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A SIMPLIFIED PROCEDURE FOR
MAJOR THOROUGHFARE PLANNING IN
SMALL URBAN AREAS

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Joint
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by

D. K. FRENCH

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Progress Report

A SIMPLIFIED PROCEDURE FOR MAJOR THOROUGHFARE PLANNING
IN SMALL URBAN AREAS

To: J. F. McLaughlin, Director
Joint Highway Research Project

October 30, 1968

File No.: 3-7-4

From: H. L. Michael, Associate Director
Joint Highway Research Project

Project No: C-36-69D

The attached research report is a Progress Report on the HPR Part I research project "An Investigation of Major Aspects of the Urban Transportation Planning Process." This report is the first one on Part V of that project and is titled "A Simplified Procedure for Major Thoroughfare Planning in Small Urban Areas." David K. French, Graduate Assistant in Research, is the author. Mr. French performed the study under the direction of Professor H. L. Michael.

The report proposes a method of estimating future travel patterns of a community and tests the method in the Lafayette, Indiana, area. It then suggests that using the method for future travel pattern determination together with other portions of the urban transportation process might result in sound transportation plans for small cities. Such a procedure would materially reduce the cost, time and personnel requirements for an urban transportation study. The use of the proposed method as a demonstration in a small city is recommended.

The research report will be forwarded for review, comment and acceptance to the ISHC and the BPR. It is submitted to the Board for the record and comment.

Respectfully submitted,

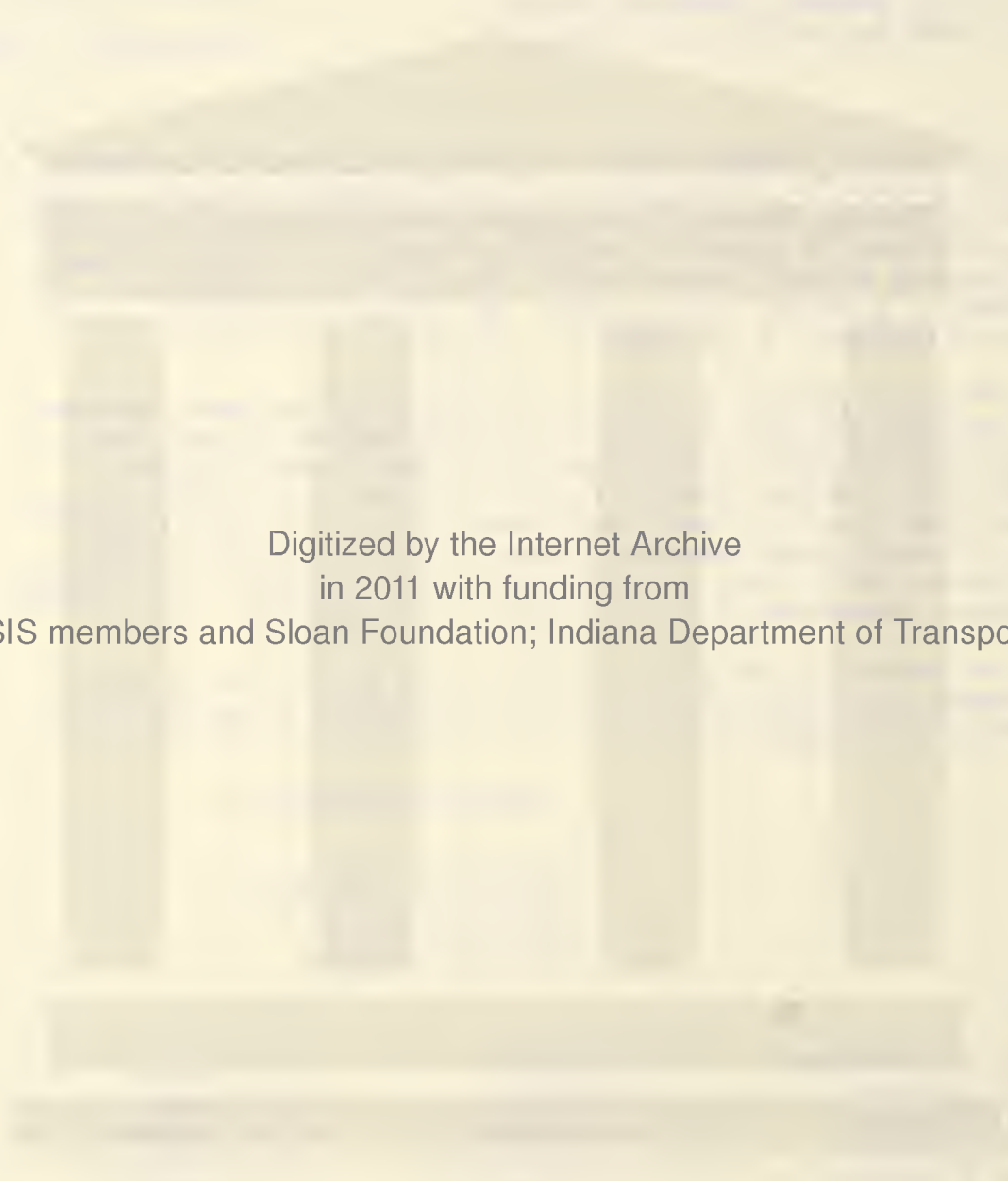
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IN SMALL URBAN AREAS

by

David K. French
Graduate Assistant in Research

Joint Highway Research Project

Project: C-36-69D

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ABSTRACT

French, David Kent. M.S.C.E., Purdue University, August, 1968. A SIMPLIFIED PROCEDURE FOR MAJOR THOROUGHFARE PLANNING IN SMALL URBAN AREAS. Major Professor: Harold L. Michael.

The need for a simplified planning procedure for small urban areas stems from two facts: (1) the cost of the home-interview origin destination survey is proportionately much more expensive for small cities than for large cities; (2) small cities have great difficulty in obtaining qualified personnel in sufficient numbers to perform the presently used transportation planning process.

The travel patterns of small cities may be relatively simple and stable over time. Thus a procedure for forecasting future volumes based on present traffic volumes may be valid. A growth factor-corridor method was developed and tested in the Greater Lafayette, Indiana, Urban Area (population 65,000). Growth factors, based on the increases of employees, retail employees, and dwelling units from 1952 to 1967, were found for each corridor. Relative trip attractiveness rates were found for the three parameters by dividing the assumed percentage of the total trips in the urban area that are represented by that parameter by the total quantity of that parameter in the urban area. This technique was

tested by applying the growth factors to 1952 traffic data and checking the results against the actual 1967 traffic data. The results were considered adequate to plan major thoroughfares in this small city.

Although only one small city was examined, the greatly simplified procedure presented appears to be feasible and adequate for major thoroughfare planning in small urban areas. The use of such a procedure will result in the savings of large sums of money in the planning process.

INTRODUCTION

In the past few decades the art of transportation planning has received an increasing amount of effort and attention. At the present time there are over two hundred transportation studies in various stages of development in the standard metropolitan statistical areas of the nation. In addition to this, many universities, consulting firms, and other research organizations are contributing a great amount of knowledge to the field.

Most of this effort has been directed toward the extremely complex, multi-modal systems of the larger urban areas. The techniques that have evolved, quite naturally, are complicated and require large sums of money and a highly qualified staff to perform. A search of the voluminous literature produces little research and few recommendations for procedures dealing specifically with the smaller urban areas and their less complex problems.

For the purposes of discussion a "small urban area" will refer to a geographically separate urban area with a single dominant city center. In general, these areas will contain less than 100,000 population. In these areas mass transit will play a very small role, and a freeway network is generally not needed. Therefore, the transportation problems

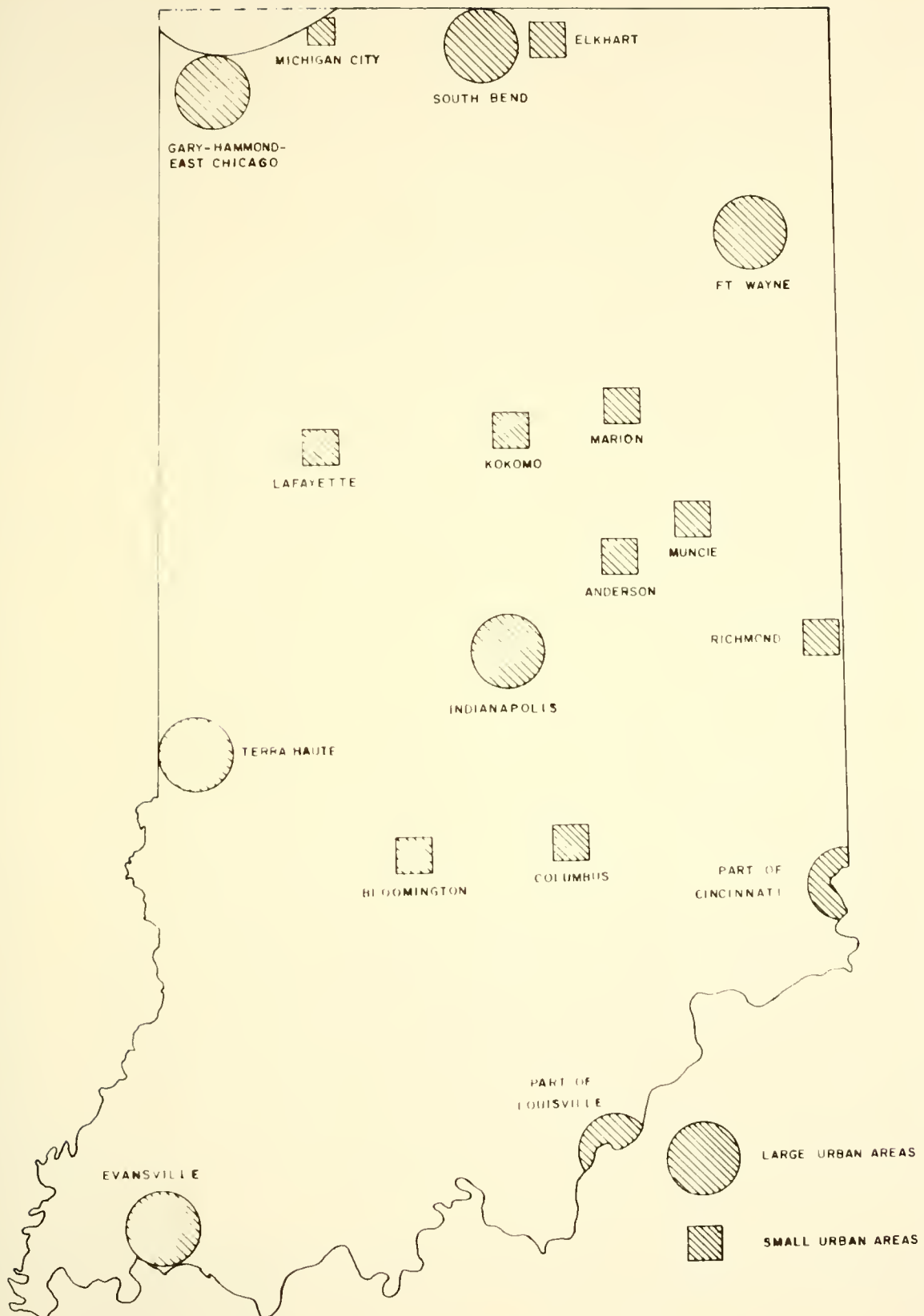


Figure 1. Urban Areas of Indiana

center around providing a good arterial system. However, in the absence of other well defined techniques, these smaller areas have had to employ essentially the same techniques as the larger areas.

The large number of cities attempting to perform transportation studies have caused a serious shortage of qualified personnel. For example, the State of Indiana has six large (over 100,000 population) and ten small urban areas (between 25,000 and 100,000 population).

In addition, part of the Cincinnati, Ohio, and Louisville, Kentucky, metropolitan areas lie in the State. These are shown in Figure 1. The smaller areas find it increasingly difficult to compete with the larger cities for qualified personnel and state funds. For this reason many of the areas below 50,000 population, who are not required to engage in comprehensive transportation planning, do not do so.

However, these cities are in need of planning. Cowdery (7)^{*} states the following:

Unfortunately, the smaller communities are experiencing traffic congestion problems which cause economic losses, delays, confusion, and hazards to safety, indicating that their major street and highway system is not functioning properly and is a hindrance to proper city expansion.

Therefore a simplified planning procedure is needed for small urban areas. This procedure should avoid the high cost

^{*} Numbers in parentheses refer to entries in the Bibliography.

of the home-interview O-D survey. It should also be simple enough for a small staff to perform, update, and re-evaluate. Furthermore, the procedure should lead the planners to rational solutions of the problems that face small urban areas.

PURPOSE AND SCOPE

The purpose of this research may be stated in three parts:

1. Examine the presently recommended procedures for transportation planning to determine what simplifications might be made for small urban areas;
2. Develop the necessary simplified techniques;
3. Demonstrate the use of the simplified methodology in a small urban area.

The scope of the research here reported will cover the first two of the three purposes stated above. The third purpose is recommended to be conducted as future research.

The methodology proposed in this research is directly applicable to cities which have not been declared standard metropolitan statistical areas. Those small urban areas that are SMSA's may also be able to use this method.

The location of major thoroughfares and the number of lanes for each are the main output of long range transportation planning. The need and general location for special structures and intersections must also be determined. However, detailed traffic operations and route locational analysis are not of concern.

REVIEW OF LITERATURE

Since few transportation planning techniques have been developed specifically for small cities, an examination of the techniques that are currently used by all cities, regardless of size, is necessary. The following discussion will serve three purposes:

1. Identify the techniques that are currently available;
2. Identify the simplifications that have been proposed for small cities;
3. Offer a direction for developing further simplifications for small cities.

There are many related studies which should be conducted simultaneously with, or prior to the transportation study. Some of these related studies deal with land use, population, economic base, redevelopment, and financing. The discussion here will assume that the needed information from such studies will be available.

Transportation planning may be divided into five parts: data collection and analysis, forecasting travel patterns, identifying future deficiencies, developing preliminary plans, and plan evaluation. These parts are not definitely distinct, but they will be discussed in these categories for clarity.

Data Collection and Analysis

The data collection and analysis phase of the transportation planning process is well outlined by the National Committee on Urban Transportation (32). The six steps in data collection are as follows:

1. Street use,
2. Origin-destination and land use,
3. Existing level of traffic service,
4. Existing level of transit service,
5. Inventory of the physical street system,
6. Financial records and reports.

Each step is presented in a procedure manual published by the Public Administration Service (PAS). Step 3, the existing level of traffic service, is divided into six parts. Four of these (traffic volumes, travel time, parking, and accidents) are each presented in a procedure manual. Street capacity is presented in Highway Research Board Special Report 87, Highway Capacity Manual, 1965, while traffic control devices are presented in a manual by the Bureau of Public Roads entitled Manual on Uniform Traffic Control Devices for Streets and Highways. These publications provide the methodology for data collection and analysis.

Existing deficiencies are determined by comparing the street system to standards; suggestions for such standards are set forth in another PSA manual entitled Standards for Street Facilities and Services. These standards consider the

following items:

1. Street configuration

spacing

continuity

service to major traffic generators

circulation within neighborhoods, central business district

conflicts with schools and school crossings

delimitation and buffering of residential areas

connection to external routes

provision for external-external traffic

presence of weaving or merging routes

2. Street Service

travel speed

volume to capacity ratio

accident rate

structural condition

3. Terminal facilities

loading and unloading of passengers and goods

parking

The standards are presented in the framework of street classification and can be considered as the basic requirements for the thoroughfare system to be planned. For this reason these standards are important, not only in determining existing deficiencies, but in identifying future deficiencies, developing preliminary plans and plan evaluation.

Only one part of the initial data collection, the origin-destination survey, will be discussed further. The street patterns of most large cities are extremely complex. A maze of alternating land uses over many square miles produces travel patterns that are equally as complex. Because of congestion or the absence of routes along the desired path, street volumes may not represent travel patterns. For this reason the origin-destination survey was devised.

A home-interview origin-destination study requires drivers to be interviewed in their homes to determine where, when, why, and how trips are made by the occupants of that dwelling unit. Since to interview every dwelling unit would be prohibitively expensive, a method of sampling is used. The size of the sample varies with the size of the urban area so that reasonable accuracy may be obtained in all cities. The sample rate presently recommended by the Bureau of Public Roads is given below (32).

<u>Metropolitan Population</u>	<u>Sample Rate</u>
, Under 50,000	20%
50,000 - 150,000	12-1/2%
150,000 - 300,000	10%
300,000 - 500,000	6-2/3%
500,000 - 1,000,000	5%
Over 1,000,000	4%

Along with the home interview, an external cordon survey and a truck and taxi survey are usually conducted. The

external count entails stopping a sample of vehicles as they cross the outer limit of the study area. Information regarding trip purpose, origin, destination, etc. is obtained. Truck and taxi trips are usually obtained at their base of operations.

The origin-destination portions of the transportation planning process may cost as much as all the rest combined. The National Committee on Urban Transportation gives these cost figures for the external cordon and home interview studies (32):

<u>Metropolitan Population</u>	<u>Total Cost</u>	<u>Per Capita Cost</u>
50,000 to 150,000	\$30,000 - 85,000	\$.60
150,000 to 300,000	68,000 - 135,000	.45
300,000 to 500,000	85,000 - 150,000	.30
500,000 to 1,000,000	112,000 - 225,000	.22

The above cost figures are probably low for today, but the relative cost for city size is probably accurate.

Jefferies and Carter conducted a letter survey of state highway agencies in 1966 (24). From this they reported that the cost of home interviews varied from \$20.00 to \$40.00 per interview and constituted "more than half of the total cost of the transportation phase of the transportation and land use planning process." Assuming an average cost of \$30.00 per interview, 3.5 persons per dwelling unit, and a 12-1/2% sample, the cost of the home interview survey would be slightly greater than \$1.00 per capita in a city of

50,000 people. Likewise, in a city of 30,000, using the recommended 20% sample, the cost of this data collection would be \$1.70 per capita.

From the foregoing it is evident that transportation planning is relatively much more expensive for small cities than for larger cities. This higher per capita cost is primarily due to the larger home interview sample percentage required in the smaller cities.

Some methods have been developed to eliminate the tremendous number of man-hours required to conduct a face to face home interview. Some of these methods utilize telephone interviews (6), mailed questionnaires to registered automobiles, return by mail questionnaires distributed to passing motorists or transit riders, or interviews at places of large traffic generators (for example: regional shopping centers, manufacturing plants, etc.) (31). Mailed post cards followed by an instructional television program (30) have also been used. All these methods have distinct advantages in that through each, a much larger sample may be obtained, at a greatly reduced cost. However each method has disadvantages in that a certain amount of bias is obtained, particularly in those surveys which require people to return the questionnaires on their own initiative. The extent of this bias for a specific study is usually unknown. Another disadvantage is that since a larger sample is normally acquired, the time and expense of coding, punching, and analyzing the

data are increased. These simplified methods appear to have received only limited use, probably due to the disadvantages noted above.

The need for and the validity of using greatly simplified techniques to estimate travel patterns was recognized by the National Committee on Urban Transportation (32). They suggested that:

An External Cordon Survey should give adequate information in cities between 5,000 and 75,000 population in which the predominant traffic flow is on through routes, few complications are imposed on the over-all street pattern, and transit is not much of a factor.

They go on to suggest that a parking survey is recommended in addition to the external survey if congestion and parking problems are concentrated in the central business district. The reasoning behind the foregoing stems from the fact that a large portion of the traffic problems in these small cities is due to traffic which is destined for the central business district from outside the urban area (external-internal traffic) and from traffic passing through the area with neither origin nor destination in the area (external-external traffic). However, many cities of this size have sufficient internal-internal traffic to significantly affect traffic flow on the major thoroughfares. For this reason some additional analysis of such traffic may be needed.

Forecasting Travel Patterns

The origin-destination survey only provides information about the base year travel patterns. Estimates of future travel patterns are needed to provide an estimate of where and what kind of improvements will be needed.

Growth Factor Models

The earliest method of travel pattern forecasting utilized a uniform growth factor. A single growth factor was derived for the urban area and applied to each zonal trip interchange obtained from the expanded origin destination study. Such a method does not account for uneven growth or for land use changes.

To account for uneven growth, the average growth factor method was devised. First, a growth factor is developed for each zone. Then, the present trip interchange is multiplied by the average of the growth factors of the two zones in question. This is done for all zonal pairs. The total trips distributed to a single zone is compared to the product of the growth factor for that zone and the present number of trips generated in that zone. If these two numbers are not equal, a growth factor is calculated from the ratio of those two numbers. Trips are redistributed and the process is repeated until the ratio becomes unity.

A refinement for the growth factor distribution method was proposed by Fratar in 1955 (12). The procedure is similar to the above procedure except that the trips estimated

between two zones are considered to be proportional to the present movements out of a zone modified by the growth factor of the other zone. A computer program is available for this method. It is recommended for use in distributing trips among external stations (38).

Another method of growth factor trip distribution was developed in Detroit (4). This is also similar in methodology to those mentioned above except the present trip interchange is multiplied by the product of the growth factors of the zones in question, and divided by the growth factor for the total area.

Growth factors for zones may be obtained by using a variety of parameters. One method requires that zones contain a single land use. This may require such a large number of zones that the distribution becomes cumbersome. Dwelling units, population or auto ownership or a combination of the three may be used as parameters for residential zones. Employment or acres of industrial land may be used for industrial zones. Acres of commercial land or retail sales may be used for commercial zones.

Another method of obtaining growth factors uses the trip purposes obtained for each zone from the origin-destination study. The trips from each trip purpose are forecast separately by the above parameters and then summed for each zone. This permits zones to be as large as is desirable for other phases of the planning process.

All growth factor methods have the disadvantage of not being able to incorporate zones which presently have no trips in them. Even if a single trip is assumed (so that something greater than zero is obtained by applying a growth factor) the growth factors tend to be very large and may distort the distribution. This objection is not too severe if there are few zones which have zero trips at the present. Similarly, inaccuracies are obtained if large changes occur in the travel patterns from the base to the design year.

Perhaps a more serious objection to the growth factor distribution methods is the necessity of having current zone-to-zone travel desires. Such zonal trip pattern data normally result from the expanded origin-destination data. Thus an O-D study is normally conducted in each city and at the recommended sample size in order to provide sufficiently accurate data.

Gravity Model

Another method of travel pattern forecasting which has been used widely and is a method recommended by the Bureau of Public Roads is the gravity model. This method assumes that the trips produced in a zone are distributed among all other zones in proportion to the relative attractiveness of these zones and inversely proportional to the resistance to travel between the zones. The methodology and necessary computer programs are well documented and the method has proven to be reliable (38).

Before the gravity model can be used to forecast future trip patterns, it must be "calibrated" utilizing existing O-D data. The trips produced from and attracted to each zone are obtained directly from the expanded O-D survey. The resistance to travel factors or "friction factors" are usually developed through a trial and error procedure. These factors are adjusted until the trip length frequency distribution by trip purpose produced by the gravity model matches that of the O-D survey. So-called "K" factors may also be necessary in order that the gravity model may reproduce travel patterns to major traffic generators to match the expanded O-D data. Likewise, certain topographical features may influence travel patterns differently than the rest of the area. Thus it may be necessary to put travel time penalties on links influenced by these features.

The accuracy of the gravity model in reproducing present travel patterns may be estimated by comparing the interzonal trip interchanges obtained from the gravity model to those obtained from the expanded O-D survey. This comparison is usually made by grouping all interzonal interchanges within a certain volume range. The difference between the gravity model and the O-D data may be great for any single interzonal movement. However, the percent route-mean-square error for any volume group should be small.

It is important to note here that quite large errors may be present in the expanded O-D data. A graph indicating

the expected error for various volume groups and various sample sizes has been prepared by the Bureau of Public Roads (38). Thus, the only reliable method for checking the gravity model against actual trip distribution is to check the trips distributed across a screen line against actual traffic volume counts across that screen line. The estimated volume is normally considered adequate if it is within 10% of the actual volume.

After all the noted comparisons have been found acceptable, the gravity model is considered "calibrated." The friction factors as well as any "K" factors and any adjustments due to topographical barriers are used to distribute future trips. The input needed in this phase is an estimate of the trips produced and attracted from each zone by trip purpose. These estimates are usually obtained from regression equations derived from the O-D survey. Trip generation rates may also be used based on land use or other appropriate parameters.

The above gives a very general and simplified picture of this phase of the transportation planning process. A detailed discussion may be found in a Bureau of Public Roads publication on traffic assignment and trip distribution for small urban areas (38). Several simplifications are noted in this publication that may be used in small urban areas. Among these are (1) the use of auto driver trips instead of person trips because modal split may be of little

importance; (2) the use of three trip purposes instead of six or more (this is often helpful in that zonal trip interchanges may be so small that many trip purposes would decrease the statistical reliability of the data); (3) trip linking may not be necessary; and (4) "K" factors are probably not needed. In addition to these simplifications the computer programs presented in this booklet require less time and will operate on a smaller computer than programs that are also available for the large city.

Although these simplifications help to reduce the time required in the data analysis phase they do little toward reducing costs in the data collection phase. For this reason there have been several attempts to reduce the required O-D sample or to "borrow" the parameters needed for calibration from other cities. Some of this research as applied to small cities is briefly discussed below.

One of the first studies to use the "borrowing" technique was performed in Iowa in 1960 (40). Travel forecasts were needed in the seven largest cities in Iowa. Six of these cities had populations which ranged from 54,000 to 92,000 while Des Moines had a population of 209,000.

A gravity model was calibrated from a full O-D survey conducted in one of the cities. Trip production and attraction rates were obtained by dividing the total trips for a given purpose by the total quantity of an appropriate parameter. For example, the total number of home-based-work trips

was divided by the total labor force to obtain an average trip rate per laborer. This rate was then multiplied by the number of laborers in each zone to obtain the number of home-based-work trips generated in that zone. Travel time-distance relationships (friction factors) were also developed. This information was then used as input into gravity models in the other six cities.

Thus, only one O-D survey was conducted and models for seven cities were obtained at a considerable savings in cost and time. The results were deemed satisfactory, although the authors recommended that a small O-D sample be conducted in each city to check trip generation rates and friction factors.

A small sample was tried in Sioux Falls, South Dakota (population 62,000) (2). It was reported that 600 home interviews coupled with standard external cordon interviews, a truck-taxi survey, and detailed socio-economic data were sufficient to calibrate a gravity model. These interviews were used to establish trip generation rates in much the same manner as was used in Iowa. Friction factors were also obtained. The small sample also provided checks on trips distributed to large attractors such as the central business district.

A study conducted in Fayetteville, North Carolina (population 76,000) produced similar results (22). A variety of subsamples were taken from the original edited 12-1/2% O-D sample. The results of the gravity models that were calibrated

from the different subsamples did not differ significantly. Most of the variation that was observed was judged to be due to the trip production and attraction rates obtained for each subsample. These rates were established by pro-rating the total trips by purpose to appropriate parameters in each zone.

Another attempt to reduce the size of the O-D sample was performed in Hutchinson, Kansas (population 37,000) (37). The concept of cluster sampling was employed here. Of the original 83 O-D zones, 14 were selected for sampling. The 14 zones offered a variety of socio-economic and other conditions. Regression analysis was used to determine trip generating rates. The regression equations contained seven terms and, therefore, required considerable data input. The calibrated gravity model was deemed satisfactory in its ability to reproduce existing travel patterns when compared to a complete O-D survey.

However, Heanue and Hamner (17) concluded from work done in Pittsburgh that cluster sampling did not provide sufficient data for developing estimates of zonal trip generation or for estimating travel time factors.

The New York Department of Transportation has used a small O-D sample in several small cities (34). Only 250 interviews, corresponding to a 0.7% sample, were taken in Elmira and Chemung counties (population 120,000). This data was used to estimate total trips per household, trip frequency distribution and overall distribution by land use.

Some concern has been expressed over the trip generating rates or equations that are developed from a reduced O-D sample. A study performed in Kingston (population 63,000) and Barrie (population 22,000), Ontario, evaluated the ability of reduced sample sizes to develop regression equations (16). Sample sizes of 10%, 5%, and 2.5% were taken from the original 12-1/2% sample. The size of the sample "does not appear to affect significantly the accuracy of trip estimates..." obtained from regression equations.

A different approach was taken by Jefferies and Carter (24). Origin-destination data was obtained from six cities ranging in population from 41,000 to 178,000. A log-log relationship was found between home-based-work trips and automobiles per dwelling unit. An equation was developed for each of the six cities. These equations were then combined, and other terms relating to density of the city and proportion of land in residential use were incorporated so that a single equation evolved for all six cities. The validity of the equation has not been tested in cities other than those used in the derivation.

The synthesizing of traffic distribution by the gravity model calibrated with a small O-D sample appears to have considerable merit. The advantages in terms of money and time saved over the conventional complete O-D study appear to greatly off-set any decrease in accuracy. However, this type of synthesis requires highly competent, experienced

personnel to obtain satisfactory results. A large staff is required to code and analyze the data.

A much simplified procedure has been used by Knox in two small cities in California (27). This work utilized a completely synthesized gravity model. Zones were established so that the intersections of major streets were at the centroids. This aided in manual traffic assignment. The number of dwelling units, commercial floor area, and jobs were obtained for each zone. Only two trip types were used: person work trips and other person trips at the peak hour. The percentage of total peak hour trips per dwelling unit by trip purpose was assumed, as was the trip production rate per dwelling unit. The time distance relationships derived in Baltimore were used. Thus the trips produced in each zone by the dwelling units were distributed among all other zones by trip purpose by the gravity model. Trips were distributed in only one direction -- from dwelling units to jobs and commercial floor area. Thus, no check was available for the trips attracted to each zone, and no balancing was necessary.

Although the foregoing is a greatly simplified version of the presently used gravity model procedures, the assumptions required for the model may be seriously questioned. On the other hand, the intent of the model was simply to provide a guide for planning major arterials for a comprehensive plan of a small city. The model as used was considered adequate for this task. It is important to note that the

need for a mathematical model that simulated travel patterns was predicated on the fact that so many small cities in California have experienced fantastic growth. Any procedure based on past travel patterns would probably be inadequate. This condition is not typical for most small cities throughout the country.

Personnel and Cost Factors

Both the growth factor and gravity model procedures were developed in large metropolitan areas. Such procedures appear to be quite necessary to cope with the extremely complex patterns that are found in these areas. As mentioned earlier, the cost per capita of an origin destination survey increases greatly with decreasing city size. Even when a small O-D sample is used to calibrate a gravity model, the cost of hiring the required technical people and for performing the necessary computer operations is still great. For example, the total cost of the Elmira and Chemung County, New York transportation study was estimated to be \$115,000 or approximately \$1.00 per capita (34). It is significant to note that an extremely small O-D sample, 0.7%, was taken and the work was performed by the New York Department of Transportation. This department has obtained a great deal of experience in performing such studies so that little trial and error was needed. Such an organization does not exist in many states at the present.

Identifying Future Deficiencies

From the methods discussed in the previous section, estimates are made of the future travel patterns. The next step in the planning process is the determination of the magnitude and location of deficiencies that may occur in the present system by the design year if no improvements are made.

Early methods simply entailed a study of future origin-destination patterns in relationship to the present street system. This was accomplished by creating so called desire lines. These are straight lines which are drawn from each origin to each destination. The width of the line usually represents the volume of this demand.

By combining desire lines, specific movements can be studied. For example, corridor movements to the CBD, and other major generators and movements across definite physical barriers such as rivers are usually studied in this manner. By comparing the future demand represented by desire lines to the existing capacity of the streets that can serve each movement, an estimate of the lane deficiencies may be obtained. A single screen line or a series of screen lines may be helpful in pin-pointing locations of deficiencies. Typical methods of illustrating desire lines are shown in one of the procedure manuals developed by the National Committee on Urban Transportation (32).

A so-called "corridor analysis" was developed by Guyton and Pollard (15). A grid of analysis lines is superimposed

over the origin and destination zones. The lines are generally spaced between $3/4$ to $1-1/4$ miles apart. The desire lines are traced from zone to zone. When a desire line crosses an analysis line the volume is tabulated on the analysis line. When all desires are tabulated the volume on each section of analysis line is compared to the capacity of the streets crossing that same section. Grids may be oriented at any angle to the street system so that all types of movements can be studied. The method is well documented and has been used in several smaller areas. Such a procedure has considerable merit over simple desire line-screen line studies in that the analyst is able to delimit specific areas of deficiencies quickly and easily. This method may not be applicable in large metropolitan areas having very complex street patterns.

Traffic assignment has been used to indicate links of the system that may be deficient. This is usually accomplished by assigning the future travel patterns to the existing plus the committed system. The committed system is comprised of those improvements to the existing system which will be built in the near future. An initial assignment of future traffic on the existing system may be on the basis of the "all-or-nothing" technique. This technique assigns each interzonal trip exchange to the minimum time path between the zones. The output from this assignment is not intended to be a realistic reproduction of the traffic volumes that would

occur in a real situation. It is instead, an indication of the volumes that could occur if everyone took the one minimum path between zones and if there was no limit to the capacity of this path. Therefore, this method is used simply as an indicator of desirable locations and for the amount of additional street capacity.

Many transportation studies, however, have not utilized a formal capacity-deficiency analysis before developing alternatives. From a careful analysis of existing points of congestion and other existing or near deficiencies found in the first phase of the planning process, alternate highway schemes are developed and tested.

Developing Preliminary Plans

The procedure for arriving at a set of reasonable alternative plans is probably the most flexible stage of the transportation planning process. Little research has been conducted in this area (10, 41). This problem is compounded in large areas in which many modes and even new transportation technology must be considered (41).

Limiting the problem of alternatives here to highway facilities, the National Committee on Urban Transportation offers some guide lines for preparing preliminary plans (32):

1. Examine the existing and future deficiencies in view of the standards that have been set. This will point to some obvious solutions.

2. Examine the land use plan and the topographical map for good locations for new facilities. Guidelines for this step are presented by AASHO (1).
3. Attempt to minimize disruption and construction cost.
4. Adhere to the principles of laying out freeway or arterial networks. Avoid merging sections and complicated intersections.

A theoretical approach was used by Chicago (5). Optimum spacing of freeways was determined to minimize total cost for various trip end densities. This spacing provided a starting point for developing a freeway network. However, the existing freeway system and the necessity of connecting external routes greatly distorted the theoretical network.

Plan Evaluation

As in the developing of alternative plans, the evaluation of plans is far from an exacting task (41). There seems to be little agreement as to just what should be the basis of choosing the best plan. Part of the reason for this may be explained by the fact that the size and scope of the types of alternatives is so broad that perhaps a single procedure and a single set of criteria may not be possible for all transportation decisions.

The National Committee on Urban Transportation (32) suggests that,

...the soundness of any preliminary plan (or plans) developed by the city will depend entirely upon whether the proposed improvements will be able to handle anticipated traffic in accordance with the speed and safety standards.

The general procedure for testing this adequacy involves two major steps: (1) the allocation of trips to each mode under consideration and (2) the determination of the adequacy of each modal system in view of the demand. The first step is usually accomplished during the analysis of the existing travel patterns as obtained from the O-D study. The second step is analyzed through traffic assignment.

Traffic assignment may have several uses in plan evaluation. First, it provides an estimate of the volumes that can be expected on the network. Thus, links which may either be over loaded or not fully utilized may be identified. Secondly, the final assignment can give a basis for design volumes for new facilities or for upgrading old facilities.

Of the basic methods of traffic assignment, the all-or-nothing traffic assignment technique was mentioned earlier. Another technique, called proportional or diversion, assigns trips between two zones to two or more routes. The total trips are proportioned among the routes on the basis of the relative attractiveness of the routes. Attractiveness may reflect time, distance, travel cost or other suitable parameters.

Both assignment techniques may utilize a technique called "capacity restraint." This technique employs a

"feedback" from the computer during the assignment process. When a link of the network reaches its predetermined capacity, its travel impedance parameter is increased (for example, travel time is increased). In the all-or-nothing technique, new minimum paths are found for the trips in remaining zones that have not been assigned. Using the proportional or diversion method, the trips from the remaining zones are proportioned among the routes on the basis of a new relative quality of service. In either case, the order of loading the network may change the final volumes on individual links.

The Bureau of Public Roads (38) divides the procedure for plan evaluation using traffic assignment into four phases. The first phase, testing, involves an uncapacitated or free assignment of future traffic to each alternate plan, followed by capacity restraint assignment. Certain selected "trees" or groups of movements may be analyzed separately. The purpose of this phase is to piece together a few reasonable alternatives and to estimate the volumes on each link.

The second phase, analysis, is divided into four parts. The first part is an economic analysis for each alternate plan of user costs as measured by the costs of time, accidents and vehicle operation versus construction costs. Estimates of these costs are related to the volume of traffic on each link and to the final speed used in the capacity restraint assignment. The second part measures the performance of each plan by comparing such items as total vehicle

miles, vehicle hours and average travel speed. This gives some idea of the efficiency of each over-all system. The third part, design, also involves obtaining total system quantities such as total system capacity, total trips assigned, total mileage by volume groups, etc. The value of these measurements is not clear. The fourth part of the analysis for each plan, involves information about the number of families displaced, compatibility with other community projects and the regional transportation system.

The third phase, evaluation of each plan, is usually in the form of benefit-cost analysis, evaluation of the level of service, and some measure of community impact. Phase four consists of final adjustments in the selected network to eliminate "problem" areas.

Chicago (5) considered community impact in the formation of alternatives. The best plan was chosen solely on a least cost basis considering time cost, accident cost, vehicle operating costs, and construction costs. Families displaced and community disruption, as well as service to major employment, recreational and residential areas were considered in review or in detail route locational analysis.

Although traffic assignment is an extremely useful tool for estimating volumes on networks, it has some disadvantages. First of all, the accuracy of the assignments is questionable. The only check on the assignment process is the link by link comparisons of the assigned volumes using

the expanded O-D data and the actual traffic volumes. The Bureau of Public Roads (39) estimates that a non-capacitated assignment may have a weighted percent error of about 60%. Capacity restraint may reduce this error to 30 to 40%. This error, of course is not due entirely to the traffic assignment. The error is the accumulation of the errors in the origin-destination data, traffic counts, capacity calculations and the assignment procedures.

Secondly, Shiatte (36) reports that the preparation of the network for traffic assignment is a slow, time consuming and expensive operation. The total cost of traffic assignment for the initial transportation planning program for Lafayette, Indiana (population 65,000), is estimated to be \$19,500 (11). For cost reasons, the alternatives that are tested may be limited to a basic plan with a few minor alterations.

The usefulness of traffic assignment in plan evaluation also has limitations. These limitations stem from the fact that the future volumes that are predicted on the street network are derived from an assumed design year population and land use pattern. The population projection may be reasonably accurate, but the distribution of this new population within the area may prove to be quite inaccurate. It is extremely difficult, if not impossible, to predict what land will be developed by a certain year. The distribution of population will obviously affect the distribution of

traffic. Therefore, it may be invalid to accept or reject street plans solely on the volumes ascertained through traffic assignment based on an assumed design year land use pattern. This is particularly true for rejecting a route location because the route is not assigned an adequate amount of traffic. In short, traffic assignment is not a very accurate measure of how a system will be used in the future. Therefore, to base plan evaluation on the numbers obtained from such a procedure, whether the numbers are volumes or travel costs, is simply not adequate.

The thought processes behind traffic assignment as currently performed appear logical, and numbers are generated from which the best set of numbers can be chosen. For this reason, there may be a tendency for transportation planners to place considerable reliance on these "answers," a reliance which may not be warranted. Many considerations which are important in highway plan evaluation are not measured through the values obtained from traffic assignment. Some of these are the plan which disrupts the community the least, is the most flexible to alternate land use developments, enhances the growth of downtown, provides better access to major generators, etc. These considerations are only a few of the items that often are important to the community. They may be more important than the "savings" of so many dollars through reduced travel time. Unfortunately, so much time, effort, and money has gone into the process that ends in traffic

assignment that the "answers" received may outweigh all other considerations in the minds of the transportation planners. This may be one reason that many transportation plans completed in the past few years are collecting dust on shelves.

Thomas B. Deen of Alan M. Voorhees and Associates (9) had the following comment:

As technicians, we long for the simplicity and objectivity of a procedure which would combine all the diverse elements that must be considered in evaluating a set of transportation systems into a single weighted index and thus provide the answer as to which is the best system. There is danger perhaps that we go so far in this direction, that we overemphasize those elements which are measurable and which do fit into the equations, or that we substitute our own subjective ideas as to how society weights its values. The result is that our recommendations and their underlying rationales are sometimes dismissed as technical exercise.

This opinion was also expressed by Lowell K. Bridwell, Federal Highway Administrator (3).

Highway planning, notwithstanding all of its highly diverse and complicated engineering detail, is not and cannot be a completely quantifiable process in which all elements can be measured and tested and assigned numbers representing cost, capacity and other criteria going into the decision process. To do that, we almost certainly would be ignoring, or at least not giving adequate weight and value to the unquantifiable elements which are equally important.

Researchers have realized that many items must be considered in plan evaluation. Recently there have been several methodologies proposed that are capable of incorporating a large number of criteria or objectives which cannot be measured with a common unit. Three of these procedures are mentioned

here. Hill (20) proposed a method utilizing a goal achievement matrix. Requisites or constraints are established which each alternate plan must meet before it can be considered further. Goals are weighted by the community, and the various groups of people who are affected by the course of action are identified and weighted. Costs and benefits are recorded for each objective according to the parties that are affected. If all costs and benefits were quantified in the same terms, then they could be summed for each goal and for all the goals for each alternative. Hill indicates that quantification of all objectives in a common unit of measure is "highly unlikely." Therefore, "...the costs and benefits and their incidence are best stated as explicitly as possible and then left to the judgment of the decision makers."

Another method has been proposed by Jessiman, et al. (25). Again, community objectives must be identified; a parameter which best measures each objective must be chosen; a weight or utility value must be assigned to each parameter. A summary of the values assigned to all the parameters for each alternative will identify the alternative with the highest value in light of the chosen community values.

An effectiveness matrix technique was employed by Schimpeler (35). Community goals were identified and weighted. A panel of planners and engineers rated each alternative as to its probability of achieving each objective and summed

for each alternative. The alternative with the highest value was deemed the one which would achieve the most community objectives.

Three principle problems related to the use of these methods are: (1) the identification of community objectives, (2) the establishment of weights for each objective, and (3) the complexity of the processes. The first problem has been dealt with by Irwin (23), the second problem by Schimpeler (35), and the third, of course, is inherent and only time, research, and practice will reduce its effect.

The preceding discussion and methodologies have been aimed principally at evaluation among various modal systems and highway types. Once the network has been decided upon, detailed route location analysis is necessary. Again this has primarily entailed an economic analysis. That is, find the location which costs the least or which has the highest benefit cost ratio. However, there are many other criteria which must enter into this analysis. Some of these criteria might be: disruption to neighborhoods; the number of displaced persons; accessibility to establishments; traffic control and operations, etc.

One technique was developed by Harland Bartholomew and Associates (29) to incorporate many subjective aspects of route location. Several possible routes were identified and a ratio of annual user benefits to annual construction and maintenance cost was calculated for each route. These

ratios were approximately equal for all routes. Each route was then rated on a scale A to D (best to worst) for a variety of aspects which were deemed pertinent to the decision. Some of the aspects were:

1. Traffic maintenance during construction,
2. Ability for stage construction,
3. Disruption to major land uses,
4. Maximum grade,
5. Horizontal curve,
6. Ability to serve adjacent land use,

The total number of A's, B's, etc. was obtained for each route. The route with the highest number of A's was given a score of one; the second highest route received a score of two, etc. Routes with about the same number were given the same score. The process was repeated for B's, C's, D's. The total score was obtained from each route and the one with the lowest total score was given a score of one, etc.

The total user plus construction cost was calculated for each route. The least costly route was given a score of one, etc. These scores were added to the final score above and a new score was assigned to each route based on the lowest score obtained from the addition of these two scores. From this the best route was chosen. A final check was made to insure that the additional cost of the route chosen was justified through user savings over the second best route.

Although this method is very rough and has some basic faults, it is an attempt to incorporate many unquantifiable aspects into the decision making process. An imperfect method of considering these aspects is better than ignoring them or considering them only in the formation of alternate routes.

Another method for detailed route selection was used in Chicago (33). This method was developed to locate a free-way within a corridor that had been identified as having great capacity deficiencies. It was determined that improvement of the existing arterials would not provide sufficient capacity to serve the traffic at an acceptable level of service. Three categories of criteria were established: engineering aspects, impact on communities, and land use improvements. Also, three levels of analysis were used: general, intermediate and detailed. A team of experts was assembled for each of the three categories. A list of weighted criteria was developed for each category and for each level of analysis. For example, the general engineering criteria are given below with their relative weights:

- 9 BPR requirements
- 8 Future expressway plans
- 7 Control points
- 6 Geometrics and operational features
- 5 Traffic
- 4 Other modes of transportation

- 3 Preliminary cost
- 2 Directness of route
- 1 Aesthetics

A rating from 1 to 10 was assigned to each route for each criteria. The sum of the products of the weights times the rating for each criteria gave the relative value for each route. The results of the three categories were brought together and compared. Some routes were immediately eliminated. The process was repeated for the intermediate and detail levels. Finally a single route was chosen.

One of the most significant aspects of this work is the incorporation of multi-discipline teams in route analysis. The group formed for consideration of each category was composed of professionals who specialized in that category. Each group worked independently on each level of analysis.

Most route location may not warrant such elaborate procedures. A single location will probably evolve as the best at an early stage of analysis.

CONCEPTUALIZATION OF A SIMPLIFIED PLANNING PROCEDURE

Forecasting Travel Patterns

The need for a simplified planning process for small urban areas stems from two basic factors: (1) the relatively higher cost of the origin-destination survey, and (2) the difficulty of obtaining qualified personnel in sufficient numbers to perform the typical transportation planning study. The origin-destination survey as originally devised was needed to obtain the travel patterns into and within the study area. However, this may not be necessary in small urban areas.

Small cities have few major traffic generators. By thoroughly examining these generators, the street system, and the residential areas, one may be able to identify where, or if, travel patterns differ from traffic volumes. A major diversion of travel patterns may be caused by severe congestion along the most direct route or the absence of a direct route. A thorough analysis of the existing system with respect to the requirements and standards for street systems should identify the presence of either of these causes.

Many of the major travel patterns are oriented toward the central business district (CBD). The CBD is

probably by far the greatest trip attractor. Major travel corridors will radiate from the downtown toward major external routes. It is these centrally oriented corridors that usually are of the most importance. This relative importance is based on the fact that these corridors probably have the highest demand.

Extensive development along the streets, however, may severely restrict the improvement of these arterials. Furthermore, it is probable that more than a basic mile square arterial pattern may be needed near the CBD. Thus an estimate of the future demand is very necessary by corridor to determine the amount and type of facilities needed in each corridor. If the street system can handle these demands it can probably also handle the volumes in the outlying areas. Since the downtown is typically the largest traffic attractor the traffic will usually be heaviest nearer this area.

An acceptable estimate of the future traffic in each corridor might be obtained by multiplying the existing traffic volumes by a growth factor. This factor could be based on the growth of all the "activities" in that corridor. By comparing these estimated future volumes to the available capacities of the streets, an estimate of the future deficiencies may be obtained. Through this simple step, the results of the gravity model distribution and the initial traffic assignment might be duplicated.

Of course, the validity of applying growth factors directly to street volumes is predicated on the stability

of the existing travel patterns. This is not a dangerous assumption in most small cities. The growth of these cities is generally represented by a simple extension of the present patterns. If this is true, then the direct application of growth factors to present traffic volumes may be very valid. A proposed process is described in the sections which follow.

Identifying Corridors ,

A corridor is comprised of one or more major streets which serve essentially the same movement. The corridor area is composed of the "traffic shed" of the major streets. This "traffic shed" is analogous to a water shed in that any trip beginning in the corridor area and desiring to go downtown will filter through the local and collector system to the corridor arterial. With a keen knowledge of local travel habits and the relative speeds and distances on the arterials, the boundaries of corridors can be set. For the most part the boundary will be equidistant from parallel arterials if these arterials are approximately equal in their attractiveness to the driver. Centrally-oriented corridors will, in general be more narrow near downtown and wider at the external cordon line. Other corridors may also be identified along cross routes and circumferential routes.

Three base maps are needed to identify corridors: A street classification map, a general land use map, and a traffic volume map. The classification map is important in

that from this, only the important major streets can be selected for projecting traffic. The land use and volume maps are used to help identify the area to include in each corridor.

The first step in selecting corridors is the identification of the central area. This area includes the CBD and its environs. More precisely this is the area in which the radial corridors merge. The central area will generally be bound by major cross routes. The streets on the inner (CBD) side of these cross routes will carry traffic from other corridors as well as from the corridor which contains the radiating routes. The centrally oriented corridors will generally extend from this central area boundary to the external cordon line. In the actual estimating procedure, corridors may overlap or be combined at the discretion of the analyst to obtain estimates on the streets desired.

External Traffic

The traffic in many small cities may be composed of a high percentage of external-internal or external-external traffic. For this study, it was assumed that an external cordon interview survey would be conducted on major routes that cross the cordon line. For external-internal traffic, the location of the trip end within the study area is therefore known. This traffic can thus be subtracted from the existing volumes on the streets and forecast separately. Likewise external-external traffic can be estimated separately.

Developing a Growth Factor

An essential part of the proposed corridor method of forecasting internal travel patterns is the development of an appropriate growth factor for each corridor. This factor must represent all the activities in the corridor. A single parameter, such as dwelling units or population or employment will not be sufficient for all corridors. Many corridors contain dwelling units, employment centers and shopping areas as well as recreational facilities etc. All of these types of land uses have different trip generating characteristics. An additional dwelling unit, business establishment, or industrial facility will effect the traffic to different degrees. Therefore, it may be necessary to weight the relative trip attractiveness of the various land uses.

A second consideration is the relative amount of each land use that is presently in the corridor and the amount that is predicted to be there in the future. A corridor may presently have 1000 dwelling units. In the future there may be 2000 dwelling units resulting in a growth factor of two. This same corridor may have 10 jobs at present, but is predicted to have 100 jobs in the future. Thus the job growth factor is ten. Obviously, an averaging of these growth factors, even if they are weighted according to the relative trip attractiveness of dwelling units to jobs, is not sufficient. Thus the growth factor must reflect the actual increase in each land use.

One method of weighting the trip attractiveness of various land uses is to use the percentage of total trips by trip purpose. Many origin destination studies have been conducted throughout the nation. Most of these have reported the percentage of trips by purpose. By relating the trip purposes to land uses or other parameters a relative trip attractiveness can be obtained.

Curran and Stegmaier (8) reported the trip purpose percentages obtained from fifty cities scattered throughout the nation. These percentages for auto driver trips for various sized cities are shown in Table 1. This table indicates a considerable similarity of percentages for cities regardless of size.

A measurable parameter is needed to indicate each trip purpose. These parameters must be obtained easily for the present year by corridor and must be able to be projected to some future year. One of the easiest parameters to work with is simply acres of land which would attract each trip purpose. However, there may be a wide variation in the trip production rate from a given land use. For example, an industrial plant may have a large storage lot which obviously does not attract many trips. On the other hand an assembly line plant may have a very high trip production rate. The use of acres of land to indicate the number of trips has not proven to be very reliable (26).

For work and business trips, the number of employees appears to be a good indicator. The number of employees by

Table 1. Total Auto-Driver Trips by Purpose and City Size.

Trip Purpose	Metropolitan Population				
	> 1 million	1 million- 500,000	500,000- 250,000	250,000- 100,000	100,000- > 50,000
Work and Business	35.4	31.5	33.4	30.4	30.0
Social-Recreational	9.3	8.8	10.4	9.8	10.9
Shopping	6.2	8.4	8.4	9.3	8.0
Miscellaneous	12.9	12.4	12.2	14.8	14.6
Home	36.2	38.8	35.1	35.1	36.5

Source: Reference 8.

establishment may be obtained relatively easily and is probably very reliably projected.

Home trips may be indicated by dwelling units, population or registered automobiles. Any of these is probably equally reliable and equally easy to project. The choice of the parameter should be based on the ease of collecting the data.

Shopping trips have been related to retail sales, retail employees, and floor space. Retail sales may be difficult to obtain in most cities. Since the number of employees must be obtained for work trips, retail employees should require little additional data collection.

Social-recreational trips may end in restaurants, taverns, theaters, residential areas, golf courses or any number of other places. Therefore a single parameter is most difficult to obtain. The same may be said for "miscellaneous" trips. These trips may be indicated by the other three parameters, however.

Three parameters were decided to be sufficient. Total employees were used for work trips, business trips and any other trips to places of employment. Retail employees were used for shopping trips and social-recreational trips to restaurants and taverns. Dwelling units were used for trips to home and other trips to residential areas. The percentage of total trips that was considered to be measured by each parameter is given below:

Total employees	40%
Retail employees	15%
Dwelling Units	<u>45%</u>
	100%

The exact percentages are, of course, not known. Those above are believed to be reasonable. A study of origin-destination study data from similar size cities will help determine what percentages should be used in any specific city.

The above percentages were used to establish relative trip production rates for the three parameters for this study. This was accomplished by determining the total quantity of each parameter in the study area. For example, a study area may have contained 25,000 employees, 5,000 retail employees, and 20,000 dwelling units. Thus the relative average trip production rate per employee would be:

$$\frac{.4}{25,000} = 1.6 \times 10^{-5}.$$

The relative trip rates for retail employees and dwelling units respectively are given below:

$$\frac{.15}{5000} = 3.0 \times 10^{-5}$$

$$\frac{.45}{20,000} = 2.25 \times 10^{-5}$$

These rates will probably remain constant over time. Therefore, the same rate was used in both the base and design

years. Since the rates are relative, the 10^{-5} may be dropped.

The procedure used in this research for developing a growth rate for each corridor using the relative trip rates was as follows:

1. Multiply the relative trip rates by the quantity of each appropriate parameter in the base year and add the three products.
2. Repeat Step 1 using the future quantities of the three parameters.
3. The ratio of the two sums is the growth factor for that corridor.

This process is also shown in Table 2 using the assumed trip rates derived above.

Plan Evaluation

Through the process described in the previous section, reasonable estimates of future arterial deficiencies and the improvements needed can be obtained. The selection of the proper type of improvement should be based on all the requirements and standards for street systems as presented by the National Committee on Urban Transportation (32). Since for small cities, the existing street system and external routes will comprise such a large portion of the future street system, few alternative courses of action may exist. Mass transit will play such a small role, and a freeway system is not normally warranted. This reduces the

Table 2. Calculation of a Corridor Growth Factor.

(1.6 trips/employee) x (Number of base year employees in the corridor) = () trips	
(3.0 trips/retail employee) x (Number of base year retail employees in the corridor) = () trips	
(2.25 trips/dwelling units) x (Number of base year dwelling units in the corridor) = () trips	
Σ (present) trips	
(1.6 trips/employee) x (Number of future year employees in the corridor) = () trips	
(3.0 trips/retail employee) x (Number of future year retail employees in the corridor) = () trips	
(2.25 trips/dwelling units) x (Number of future year dwelling units in the corridor) = () trips	
Σ (future) trips	
Corridor Growth Factor = $\frac{\Sigma \text{ (future) trips}}{\Sigma \text{ (present) trips}}$	

alternatives to additions to the present arterial street system. In general the proper course of action will be fairly apparent.

Since the street network and the travel patterns are relatively simple, estimates of the volumes on the improved and the few new facilities may be made by "judgment" assignment of the future estimated corridor volumes. These estimates only have to be accurate enough to determine the number of lanes needed for each arterial. A major arterial should always be planned with a minimum of four lanes and few movements in a small city require more than four lanes if good traffic engineering is employed.

No procedure presently exists for choosing the best plan in light of all standards of street planning. Perhaps no procedure can be developed. Many parts of the future network will be chosen almost automatically by only the simplest consideration of the standards. Other parts will be chosen only after a careful weighting of the conflicting criteria. Therefore, the evaluation procedure will vary widely with

TESTING THE GROWTH FACTOR-CORRIDOR TECHNIQUE

Any growth factor technique can only be checked against known design year data. Therefore, to check the technique developed in the preceding chapter, a small midwestern city was chosen which had traffic volume data from some past year (1952). The technique was then applied to these past volumes and the results were checked against actual 1967 volumes. Values were obtained for each corridor for both the base year and the design year for all three parameters: dwelling units, employees, and retail employees. This information provided the growth factor for each corridor.

Study Area

The area chosen for testing the forecasting technique was the Greater Lafayette, Indiana, Urban Area. The location of this area within the State of Indiana may be seen in Figure 1. This city was chosen for two reasons. First, a traffic study was conducted in 1952 so that traffic data for a past base year was readily available. Secondly, traffic volumes on present streets could be easily obtained because of the proximity of the city to the researcher.

The Lafayette area is typical of most small midwestern cities in that it has experienced steady, but not "booming"

growth throughout the years. In 1952 the Lafayette - West Lafayette area had a population of about 49,000. By 1967 this had increased to about 65,000 or a 34% increase in fifteen years. Most of the increased population resides either south of Teal Road in Lafayette or in northern West Lafayette. The 1967 general land use map is shown in Figure 2.

The only major atypical aspect of Lafayette is that it contains Purdue University. The travel habits of the large student population are different from typical residents, and the large number of dormitories and rooming houses preclude the use of the normal definition of dwelling units. Therefore, for the corridor containing the University, the previously derived growth factor was considered inadequate. Employees of Purdue was used as the growth factor parameter.

The growth factor for external traffic was obtained from the automobile registrations of Tippecanoe County. One exception was made to this. U. S. 52 carries a large amount of statewide and regional traffic. Therefore, the growth factor for the external-external traffic on this route was based on registered automobiles in the State of Indiana. The rest of the traffic on U. S. 52 inside the urban area was forecast as internal traffic.

The streets in 1967 were classified according to standard procedures, except that a distinction was made between minor and major arterials. This was considered advantageous for later stages of the research. The street classification map is shown in Figure 3.

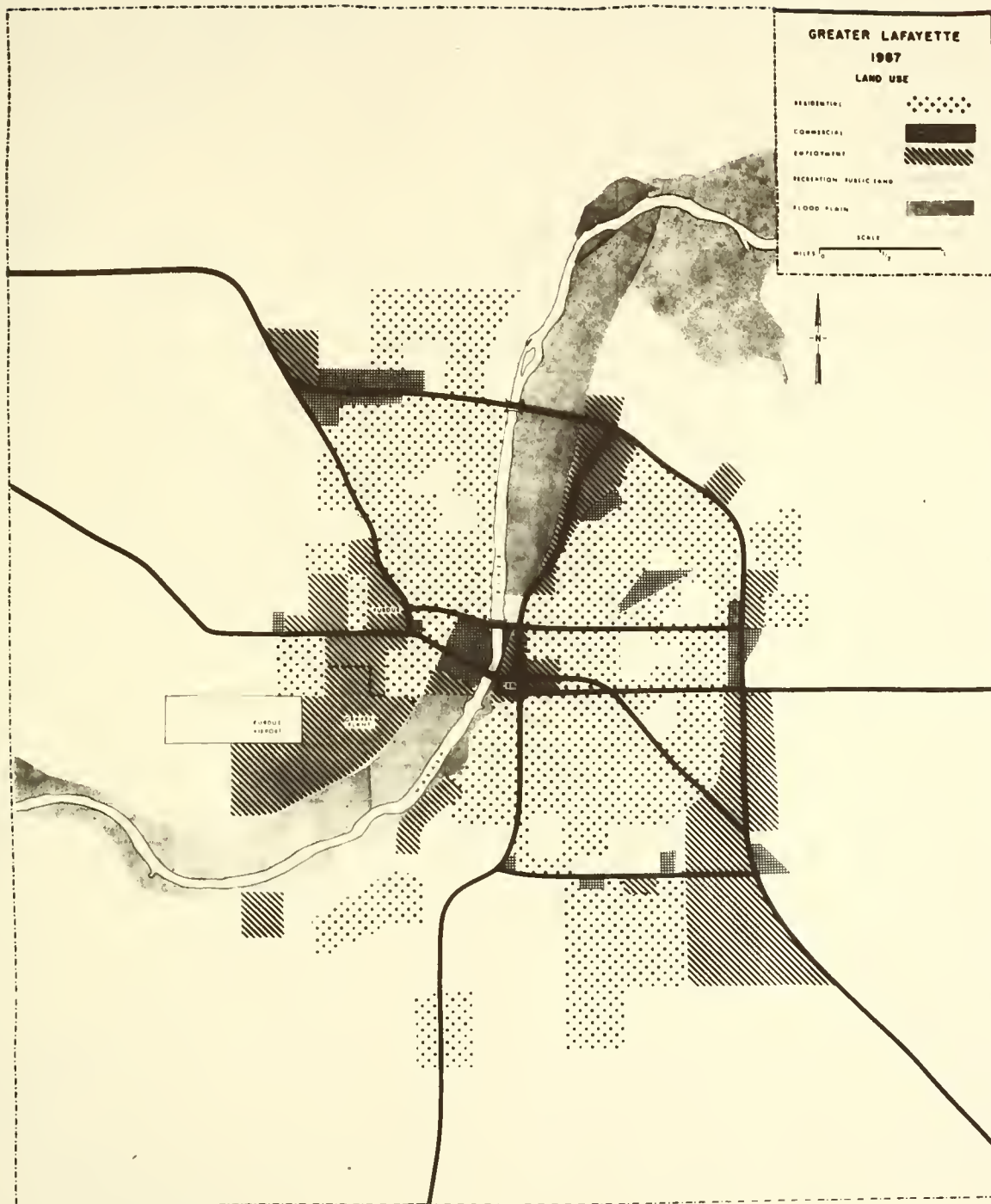


Figure 2. 1967 General Land Use Map

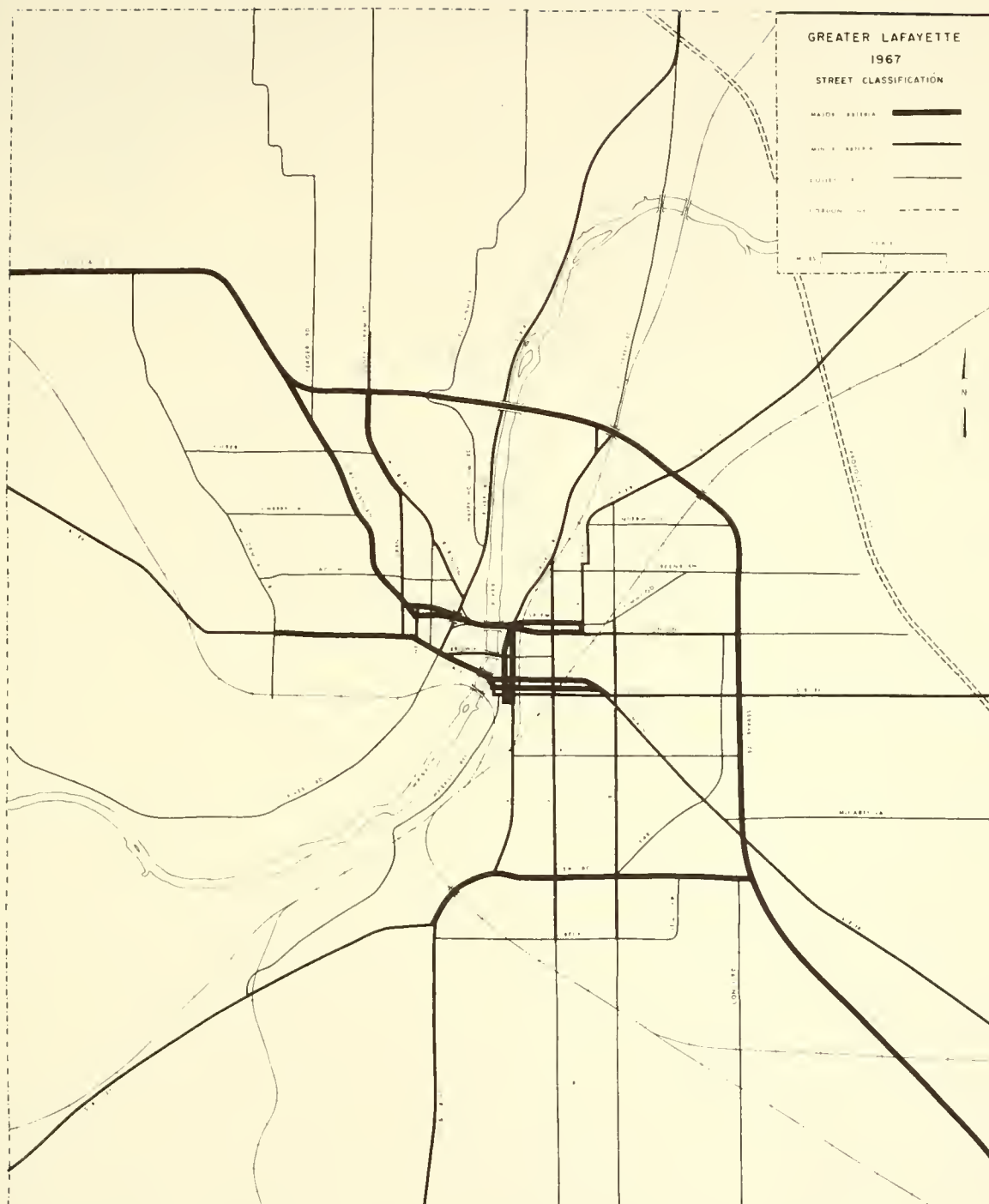


Figure 3. 1967 Street Classification Map

There were only three major changes in the street system between 1952 and 1967. A new bridge, the William Henry Harrison Bridge, was built connecting Union and Salem Streets in Lafayette to Wiggins and Fowler Streets in West Lafayette. The two sets of streets were made one-way couples. Third street was extended from Brown Street to Union Street and converted into a one-way couple with Fourth Street. Eighteenth Street was extended from Kossuth to South Street. Thus it became an arterial while Sixteenth Street was converted into a local street. Improvements were made to certain streets but their alignment or function was not altered.

Corridors were delimited using the procedures established earlier and are shown in Figures 4 and 5. Twelve principal radial corridors were established, two of which (nine and ten) overlap. In addition to these corridors, corridor eleven was established to estimate Teal Road. Corridors four, five and six were used to estimate U.S. 52 Bypass in eastern Lafayette, and corridors nine and twelve were used for U. S. 52 Bypass in northern West Lafayette. Corridors four, five, six, seven, eight, nine and twelve were used to estimate the volumes on the Bypass Bridge across the Wabash River. A growth factor based on the whole city was developed to estimate the two bridges (in 1952) near the CBD.

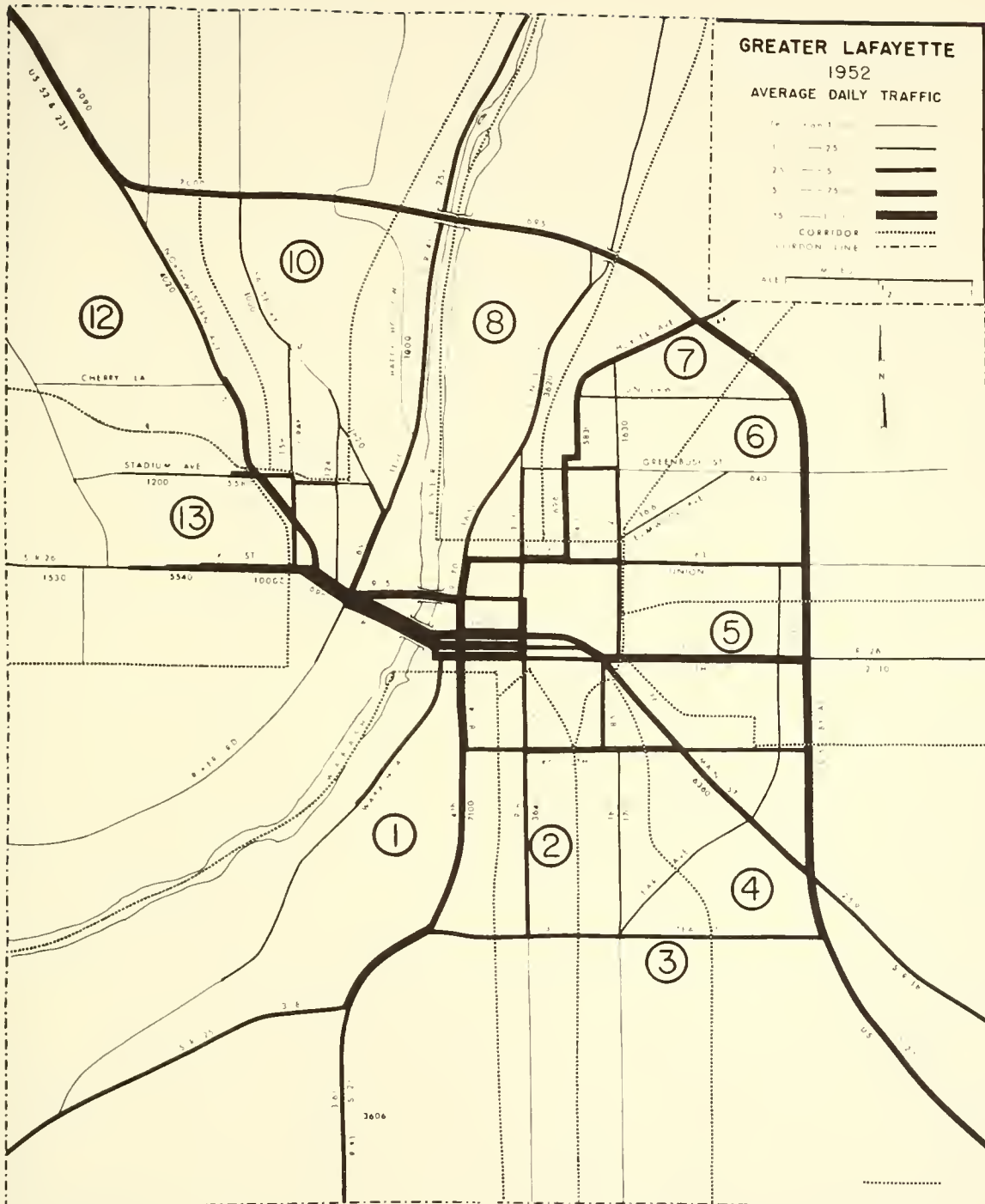


Figure 4. Corridors

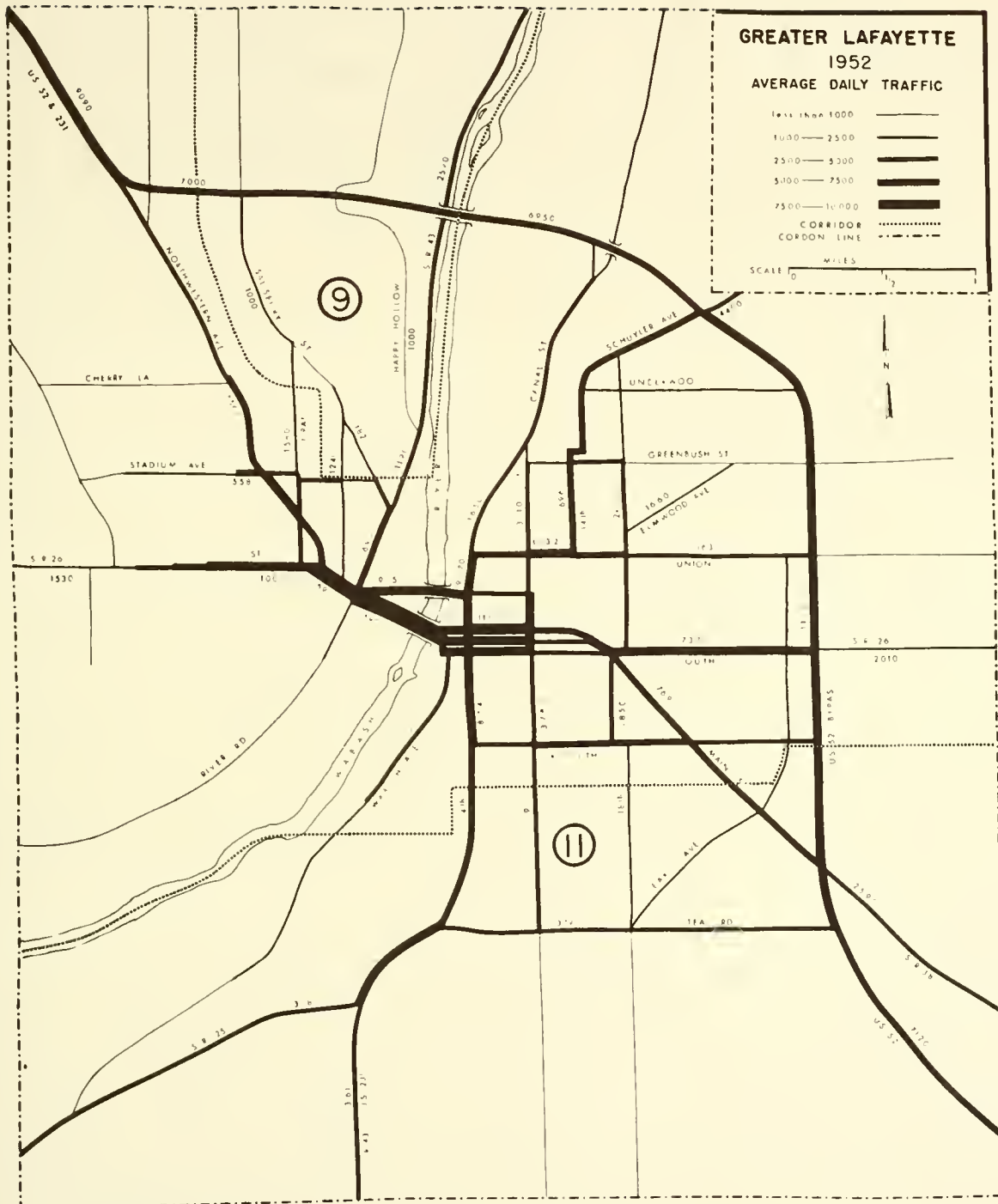


Figure 5. Corridors

Data Collection

Total and Retail Employment

Employment data for both 1952 and 1967 was obtained from the Indiana Employment Securities Division. In 1952 only those employers having more than eight employees were required to register with the Employment Division. Therefore, all employers with less than eight employees were deleted from the data for both years. A check was made on the effect of removing these small employers. No change in the resulting growth factors was found.

Telephone directories were obtained for both years. The address of each employer listed by the Employment Division was obtained from the telephone directory. In this way the employees were tabulated in each corridor. Many employers, such as food stores, had several branches. The employees were divided equally among the branches, unless personal knowledge of stores indicated another division should be made.

A few employers were not listed in the data. Therefore, additional information was obtained from a recent survey conducted of major Lafayette employers (16). From this the names, number of employees, addresses, and dates of founding were obtained for all industrial employers having over twenty-five employees. The data of founding and the date of major employment changes provided data for 1952.

Telephone calls were made to the two large hospitals to obtain employment data, and a few establishments were added

from the personal knowledge of the area by the researcher. Employment for Purdue University was obtained through personal correspondence with the comptroller's office.

Retail employees were obtained from the above total employees. Retail establishments were those having Standard Industrial Classification codes of 5250 to 5460 or 5540 to 5990. This included all retail stores, restaurants, taverns, and service stations.

All employment data is presented in Appendix A, Tables A1 and A2.

Dwelling Units

The number of dwelling units was obtained from the Lafayette City Directory and aerial photographs. The city directory provided information within the city limits of Lafayette and West Lafayette. Each address and each apartment unit was counted as one dwelling unit. The houses outside the city limits were counted from the aerial photographs. Photographs were available for 1967 and 1955. The difference between 1955 and 1952 was believed to be insignificant. This data is also presented in Tables A1 and A2.

1952 Traffic Data

In 1952 the Indiana State Highway Commission conducted a post card origin-destination survey and an external cordon interview survey. The results of this study were published in 1964 and made available to this researcher (28). The

1952 ADT volumes obtained from the report are shown in Figure 6.

The external cordon line used in 1952 included only the 1952 development. A new line was established to include the 1967 development. The movement of this line affected only two external stations: SR43 and SR25 South. Additional 1952 development was thereby included by moving the cordon line so corresponding reductions were made in 1952 external-internal traffic at the new external stations.

The external traffic was displayed in the report in the form of desire lines from external stations to internal zones or to other external stations. From these desire lines an estimate of the amount of external-external and external-internal traffic using each major street was made.

1967 Traffic Data

The 1967 ADT volumes were obtained from the Indiana State Highway Commission and the City of Lafayette. Several additional counts were obtained by the researcher by utilizing pneumatic tube traffic volume recorders. This information is shown in Figure 7.

Automobile Registration

The number of automobiles registered in Tippecanoe County and in the State of Indiana in 1950 and 1965 were obtained from published data (21, 14). This information provided the growth factors for the external traffic.

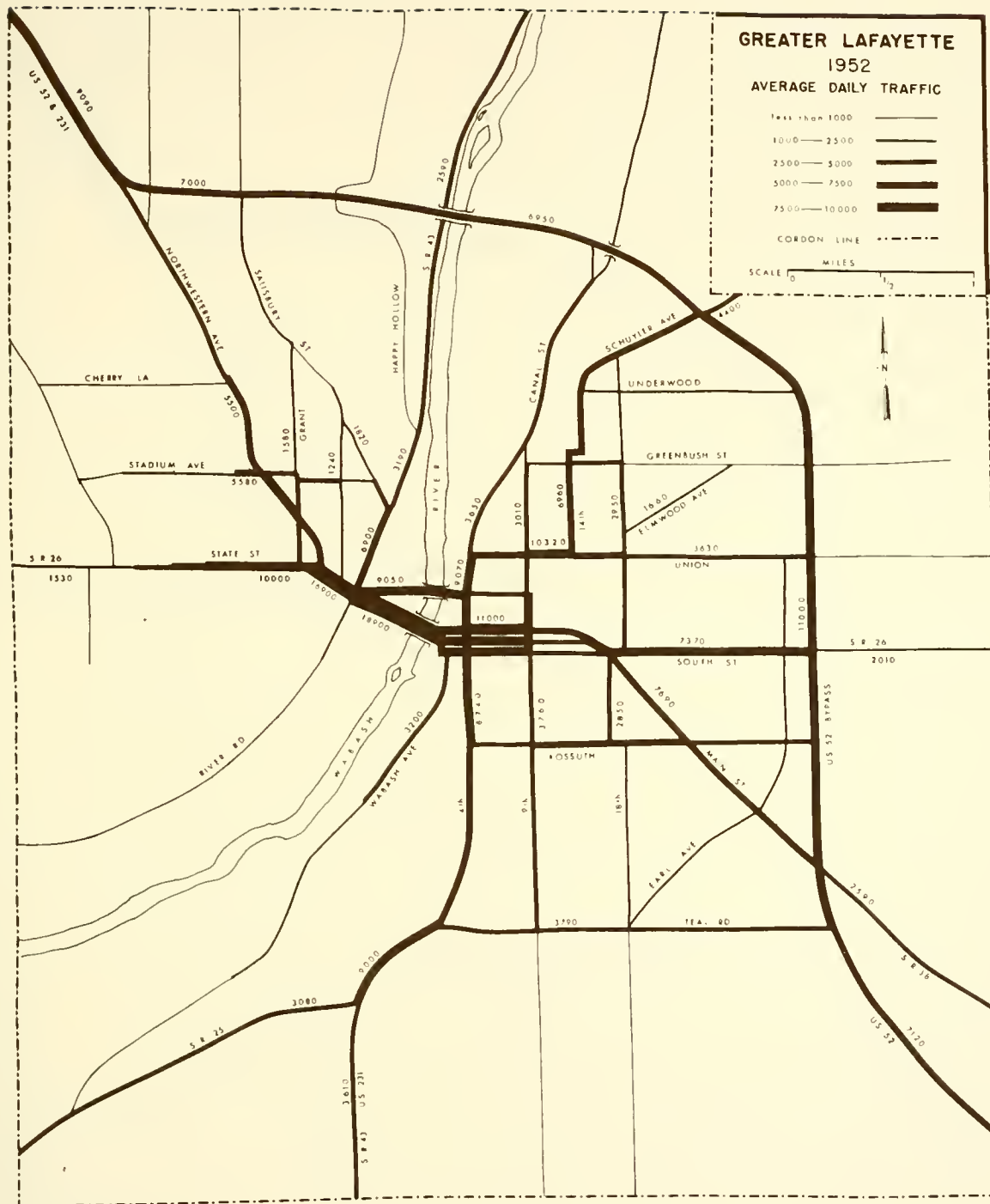


Figure 6. 1952 ADT Volume Map

Criteria for Acceptance

The growth factor-corridor technique developed in the preceding chapters has great advantages over standard procedures. This method is quick and easy to use and requires a minimum of time, money and personnel to perform. However, its value must be judged by its ability to produce adequate results. The adequacy of the results should not be measured by whether the estimated volumes are within a percentage of the actual volumes. It should be based on whether the error is large enough to cause a wrong decision to be made. In the planning of arterials, the error is significant when not enough lanes of traffic are provided, too many lanes are built before they are needed, or a wrong location for improvement is chosen.

Utilizing the techniques described in the 1965 Highway Capacity Manual (19) the following ranges of service volumes were obtained for an arterial assuming a level of service "C;" population of city = 75,000; peak hour factor = .85; directional split = 60-40; peak hour volume = 10% of ADT; G/C = .45; lane width = 10-12 feet; no parking; 20% turns:

4 lanes	12,000-15,000 Vehicles per day
4 lanes & left turn lane	15,000-19,000 Vehicles per day
6 lanes	19,000-23,000 Vehicles per day

An estimated volume in error of up to about \pm 4000 vpd for volumes under 19,000 will not greatly change the needed design of the street. For example, if the estimated volume

is just under 15,000 vpd for a street which has four lanes twelve feet wide, no improvements will be recommended. However, if the actual volume is between 15,000 vpd and 19,000 vpd then some widening may be needed at critical intersections to incorporate left turn lanes. At non-critical intersections additional green time may be obtained to accommodate the additional volumes. Thus, the underestimation by 4,000 vpd of volumes below 19,000 most often would not result in a serious or costly problem. Furthermore, volumes below the service volume capabilities of a basic four lane arterial will not affect the physical design of the street. In other words, if both the future actual and estimated volumes are below the capabilities of the street, the size of the error in estimation has little or no meaning. This gives some idea of the tolerable error permitted in forecasting volumes for street design.

Results

External Traffic

Before checking the ability of the technique to predict total corridor volumes, the validity of the external growth factor was checked. The growth factor developed for the through traffic on U. S. 52 was based on automobile registrations in Indiana. This factor was as follows:

$$\frac{1965 \text{ Automobile registrations}}{1950 \text{ Automobile registrations}} = \frac{2.4 \times 10^6}{1.4 \times 10^6} = 1.71$$

The growth factor for all other external traffic was based on automobile registrations in Tippecanoe County. This factor was as follows:

$$\frac{1965 \text{ Automobile registrations}}{1950 \text{ Automobile registrations}} = \frac{50,218}{28,152} = 1.79$$

These factors were then applied to the 1952 traffic volumes at each external station. The results are shown in Table 3. The average error was 1089 and the average 1967 volume was 7,560. Only one result was of any concern. State Road 26W had an error of slightly over -3000, however, the total volume is very small. No change in the design of the street would have occurred had the estimated volume been used in 1952 to program improvements. The appreciable error in the SR26W 1967 volume resulted from heavy development along this road well beyond the urban area between 1952 and 1967. Such development could not have been predicted. The other stations were considered entirely satisfactory.

Principal Radial Corridors

Twelve corridors radiating from the central area were defined and a growth factor for each was formed. Since some corridors contained two or more streets, the magnitude of corridor errors are not directly comparable. Therefore, estimates were made on each radial street in each corridor. The external traffic was subtracted from the volumes of the appropriate street and forecast by the external growth factor. The internal traffic was then forecast by the

Table 3. External Cordon Stations.

Route	1952 Volume	Growth Factor	Estimated 1967 Volume	Actual 1967 Volume	Error
SR25S	3,080	1.79	5,500	6,000	- 500
SR43S	3,600	1.79	6,450	5,700	+ 750
US52S	3,620	1.79	6,500		
	3,500	1.71	<u>6,000</u>		
			12,500	14,000	-1,500
SR38	2,590	1.79	4,630	5,000	- 370
SR26E	2,000	1.79	3,580	5,500	-1,920
SR25N	4,400	1.79	7,850	8,500	- 650
Canal Road	1,450	1.79	2,600	2,500	+ 100
SR43N	2,590	1.79	4,630	4,600	+ 30
US52N	5,590	1.79	10,000		
	3,500	1.71	<u>6,000</u>		
			16,000	18,000	-2,000
SR26W	1,530	1.79	2,730	5,800	-3,070

corridor growth factor and the total forecast traffic for each street was obtained. The results are given in Table 4 and Figure 8.

The average street error was 3,000 vpd and the average actual street volume was 7,985. These results in general were considered entirely satisfactory. However, a few of the estimates appear to have quite large errors.

Elmwood Avenue was underestimated by 5,050 vpd, while Union Street (in the same corridor) was over estimated by 3,700 vpd. This may be explained by two reasons. A major shopping center was built in the triangle formed by Elmwood, Greenbush and the railroad tracks. The primary entrances to the center are from Elmwood Avenue. Secondly, a traffic signal has been installed at Greenbush and U.S. 52 Bypass enabling the residents on the east side of the Bypass to easily cross this major street. Thus the Greenbush-Elmwood route is used instead of the Bypass-Union route by much traffic.

Another large error was obtained in corridor 13 containing Purdue University. The traffic on the two streets State and Stadium were over estimated by a total of 12,680 vpd. This may be explained by several reasons. Both of these streets are congested during the peak hours and simply could not handle the forecast traffic. For this reason, much traffic destined for the South Purdue Campus is diverted off State Street and onto Wood Street which in 1967 is being used as an additional arterial in this corridor. The volume

Table 4. Principal Radial Corridors Near Central Area.

Corridor	Streets	1952 Volume	Internal		External		Estimated 1967 Volume	Actual 1967 Volume	Error	
			Volume	Growth Factor	Volume	Growth Factor			Street	Corridor
1	Wabash Fourth	3,530	3,530	1.54	-	-	5,420	5,000	+ 420	-
		8,740	5,440	1.54	3,300	1.79	14,300	10,700	+3,600	-
		12,270					19,720	15,000		+4,020
2	Ninth	3,760	3,760	2.33	-	-	8,760	6,500	+2,260	+2,260
3	Eighteenth	2,850	2,850	2.99	-	-	8,500	8,000	+ 500	+ 500
4	Main	7,690	5,690	1.95	2,000	1.79	14,580	10,000	+4,580	+4,580
5	South	7,370	5,870	1.54	1,500	1.79	11,680	9,000	+2,680	+2,680
6	Union Elmwood	3,630	3,630	3.16	-	-	11,500	7,800	+3,700	-
		1,660	1,660	3.16	-	-	5,250	10,300	-5,050	-
		5,290					16,750	18,100		-1,350
7	Eighteenth Fourteenth	2,950	2,460	1.07	500	1.79	3,520	5,100	-1,580	-
		6,950	5,450	1.07	1,500	1.79	8,510	5,600	+2,910	-
		9,900					12,030	10,700		+1,330
8	Ninth Canal	3,010	2,710	1.37	300	1.79	4,250	5,850	-1,600	-
		3,650	2,950	1.37	700	1.79	5,300	7,800	-2,500	-
		6,660					9,550	13,650		-4,100
9	SR43N	3,190	730	6.10	2,460	1.79	8,850	8,300	+ 550	-
	Robinson	1,820	1,820	6.10	-	-	11,100	3,900	+7,200	-
	Salisbury	1,240	1,240	6.10	-	-	7,550	5,000	+2,550	-
		6,250					27,500	17,200		+10,300
10	Salisbury Grant	1,240	1,240	5.41	-	-	6,700	5,000	+1,700	-
		1,580	1,580	5.41	-	-	8,550	7,450	1,100	-
		2,820					15,250	12,450		+2,800
12	Northwestern	5,500	2,300	4.65	3,200	1.79	16,450	12,800	+3,650	+3,650
13	State Stadium	10,000	8,500	2.52	1,500	1.79	24,180	16,900	7,280	-
		5,580	5,580	2.52	-	-	14,100	8,700	5,400	-
		15,580					38,280	25,600		+12,680

Average Actual Volume per Street = 7,985

Average Estimated Volume per Street = 9,952

Difference = 1,967

Average Error per Street = 3,040

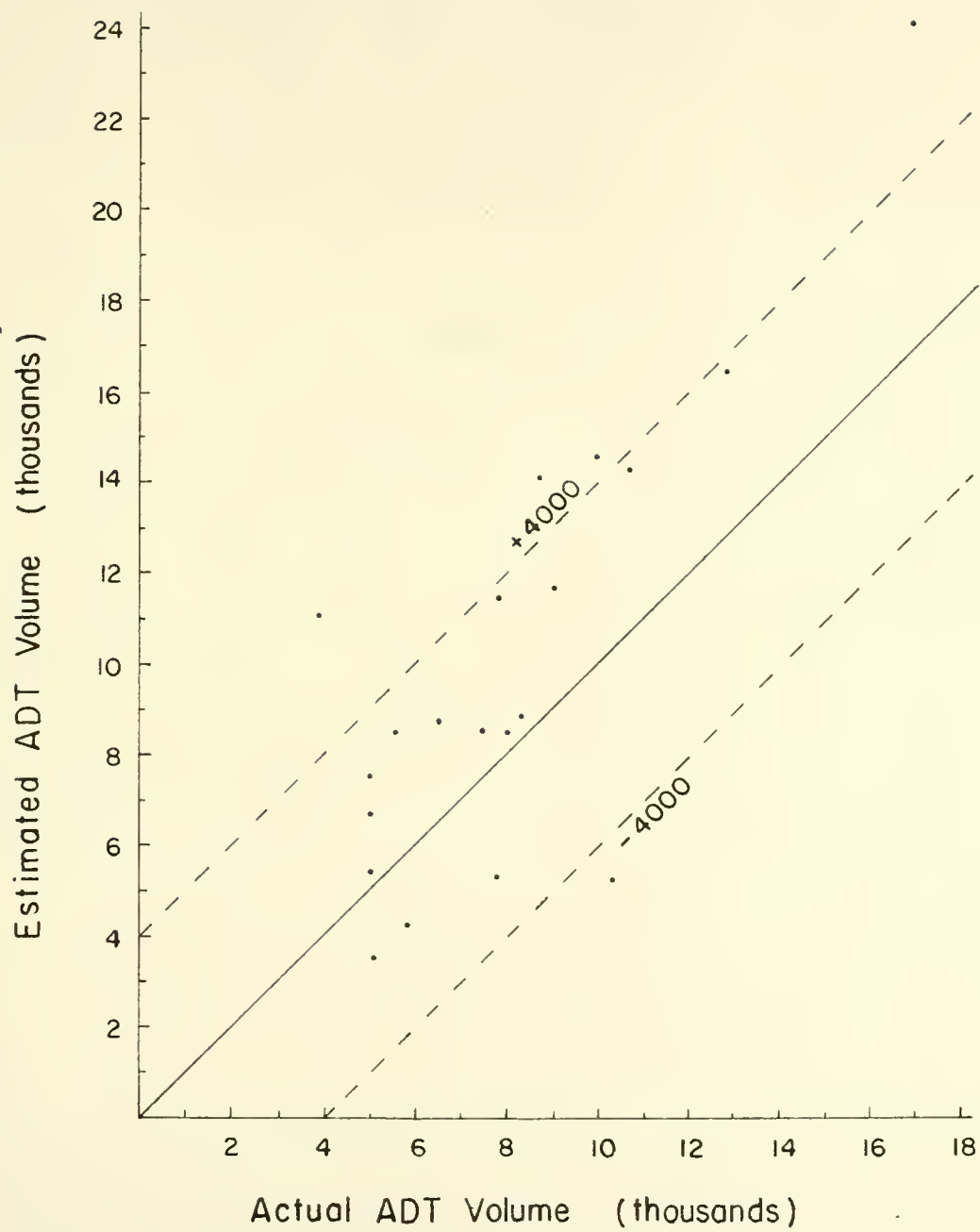


Figure 8. Principal Radial Corridors Near Central Area

on Wood Street in 1952, however, was low as it was not an arterial at that date. Thus, this traffic does not enter the section of State Street being estimated. Secondly, a major parking garage and some parking lots have been located east of the estimated section. Thus, some traffic is converted to pedestrian before entering the corridor. A third reason is that increased restrictions have been placed on student car ownership. Thus traffic may not be proportional to the growth of the University for the time period involved. A fourth reason lies in the fact that the University has built a great number of married student courts near the airport. Thus most of this traffic enters the campus from the west side. This has greatly increased the volumes on the west end of State Street while increasing the eastern part very little.

The traffic on Robinson Street was also greatly overestimated. This may be explained by two reasons. First, some traffic destined for the CBD from northern West Lafayette may be using the U. S. 52 Bypass and Canal Road. This route permits drivers to maintain about 35 mph speed from the intersection of Salisbury and the Bypass to the intersection of Canal Road and Union Street. The Salisbury-Robinson-Harrison Bridge route requires the driver to make two ninety degree left turns and to stop at one stop sign. A second explanation may simply stem from the fact that a very high growth factor (6.10) was obtained for this corridor. Any

very large growth factor must be used with caution.

Main Street was also over estimated by about 4,500 vpd. This is mainly due to the opening of Eighteenth Street between Kossuth and South Street. Some traffic has been diverted from Main to Eighteenth.

The foregoing may be summarized by the following statements:

1. The division of traffic among streets in a corridor may be altered by the specific location of a major traffic generator or by improvements in traffic operations.
2. As streets approach capacity, increased use will be made of the paralleling local streets.
3. Increased activity at the outer portion of the corridor which attracts or is attracted to other activity within the corridor may not greatly affect the traffic at the inner portion of the corridor.
4. For relatively long trips, some trips may be attracted to longer but faster routes.
5. Large growth factors must be used with caution.

These statements not only help explain some of the errors received in this forecast, but they will help guide a planner to arrive at realistic design volumes for future efforts.

From Table 4 and Figure 8, there is indication that for the most part the procedure used slightly over estimated the volumes at the inner portion of the corridor. Since the growth factor is indicative of the total growth of the corridor,

and since most of the growth will occur toward the outer portion of the corridor, perhaps better results can be obtained by applying the growth factor to volumes in the middle of the corridor. This hypothesis was tested in the exact same manner as the previous forecasts. The results are given in Table 5 and Figure 9.

The results indicate an average error per street of 2,320 vpd and an average volume of 7,290. Thus the average error was decreased by about 700 vpd from the first estimate. Of the eighteen streets in the second estimate, six showed an increase in error over the first estimate. However, no large errors as experienced in the first estimate were obtained. All of these errors, except those offsetting ones obtained from Union and Greenbush (Elmwood), are well below the $\pm 4,000$ criterion mentioned earlier. These results were considered entirely satisfactory.

Circumferential Corridors

There are two main circumferential routes -- U. S. 52 Bypass and Teal Road. Volumes were estimated in three places on the Bypass -- eastern Lafayette, the bridge over the Wabash River, and northern West Lafayette. A single location at the midpoint of Teal Road was estimated. The results are given in Table 6.

Table 5. Principal Radial Corridors Near Middle.

Corridor	Streets	Internal		External		Estimated 1967 Volume	Actual 1967 Volume	Error	
		Volume	Growth Factor	Volume	Growth Factor			Street	Corridor
1	Wabash Fourth	3,200 7,100 10,300	1.54 1.54	- 3,300	- 1.79	4,430 11,750 16,680	4,000 + 10,600 14,600	+ 930 +1,150	+2,080
2	Ninth	3,640	2.33	-	-	8,450	6,300	+2,150	+2,150
3	Eighteenth	1,930	2.99	-	-	5,800	8,000	-2,200	-2,200
4	Main	6,360	1.95	2,000	1.79	12,080	8,000	+4,000	+4,000
5	South	7,370	1.54	1,500	1.79	11,680	9,000	+2,680	+2,680
6	Union Greenbush	3,630 640 4,270	3.16 3.16	- -	- -	11,500 2,020 13,520	7,760 + 9,080 16,840	+3,740 -7,060	-3,320
7	Eighteenth Fourteenth	1,630 5,830 7,460	1.07 1.07	500 1,500	1.79 1.79	2,110 7,320 9,430	4,500 - 5,500 + 10,000	-2,390 +1,830	- 570
8	Canal Road	3,620	1.42	1,000	1.79	5,010	6,770	-1,760	-1,760
9	SR43N Happy Hollow Salisbury	2,590 1,000 1,000 4,590	- 6.10 6.10	2,590 - -	1.79 - -	4,630 6,100 6,100 16,830	4,600 + 3,700 7,400 15,700	+ 30 +3,600 -1,300	+1,130
10	Salisbury	1,000	5.41	-	-	5,410	9,000	-3,590	-3,590
12	Northwestern	4,020	4.65	3,200	1.79	9,420	10,000	- 580	- 580
13	State Stadium	5,540 1,200 6,740	2.52 2.52	1,500 -	1.79 -	12,780 3,020 15,800	12,000 + 5,000 17,000	+ 780 -1,980	-1,200

Average Actual Volume per Street = 7,290

Average Estimated Volume per Street = 7,230

Difference = 60

Average Error per Street = 2,320

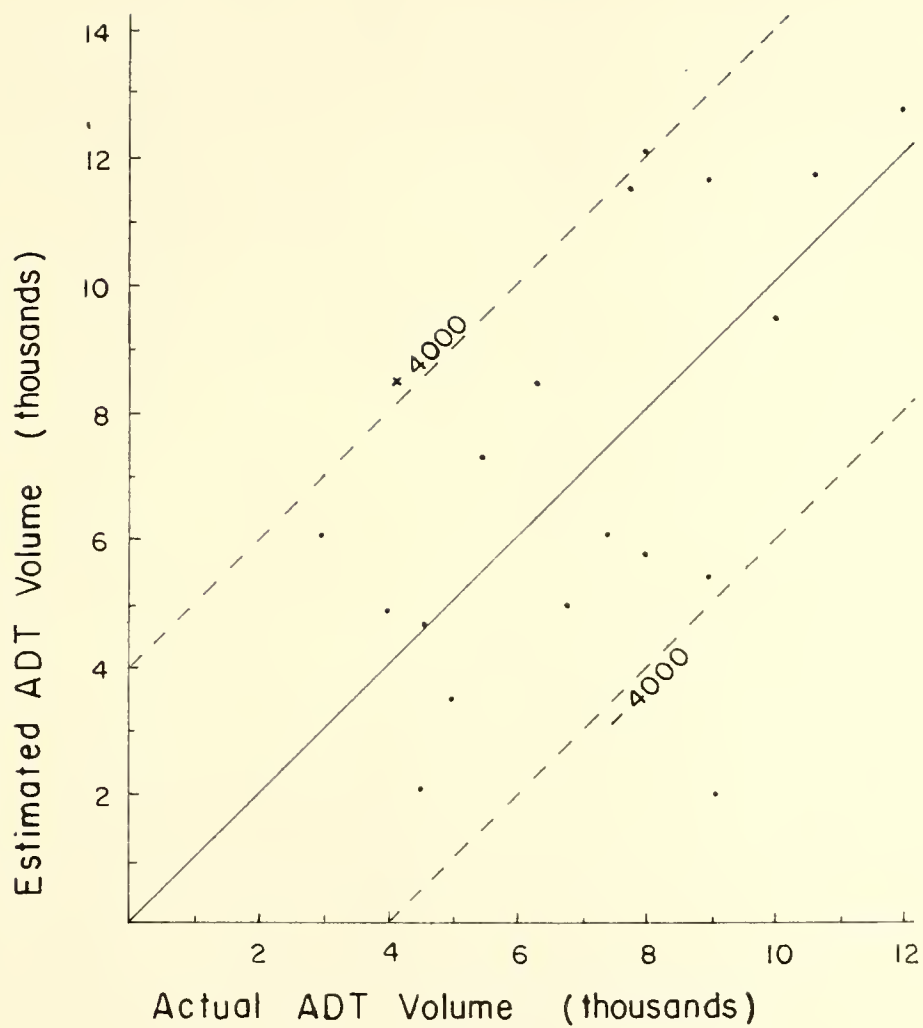


Figure 9. Principal Radial Corridors Near Middle

Table 6. Circumferential Routes.

Route	Location	1952 Volume	Internal		External		Estimated 1967 Volume	Actual 1967 Volume	Error
			Volume	Growth Factor	Volume	Growth Factor			
US 52 Bypass	Eastern Lafayette	11,000	7,500	1.97	3,500	1.71	20,800	22,000	-1,200
	Wabash River Brid.	6,950	3,450	1.88	3,500	1.71	12,500	14,600	-1,900
	No. West Lafayette	7,000	3,500	4.41	3,500	1.71	21,440	17,000	+4,440

Teal Road	Midpoint	3,790	2,990	2.99	800	1.79	10,380	12,500	-2,120

Central Area Bridges

In 1952 two bridges across the Wabash River, Main-State Street and Brown Street, linked the CBD to West Lafayette and Purdue University. These are, of course, of vital importance to the community and provide a critical point in the network. An estimate of the volumes was made for 1967 using the growth factor developed from the parameters relating to the whole urban area. A third bridge, William Henry Harrison, was added in 1961 and serves much the same movement as the other two. Thus the actual 1967 volume was obtained from the total of the three bridges. The results are given in Table 7 and are considered entirely satisfactory.

Table 7. Central Area Bridges.

1952 Volume	Growth Factor	Estimated 1967 Volume	Actual 1967 Volume	Error
27,960	1.62	45,200	49,200	-4,000

Conclusions

The growth factor-corridor technique appears to give results that are adequate to determine what major arterials are needed. The results were sufficiently accurate to indicate the number of lanes needed and to provide the information required for major intersection design and operation in

the one city in which it was tested. As with any presently used technique, the individual results must be evaluated for reasonableness. Some caution may be required when estimating volumes in each corridor near the CBD because of the tendency to overestimate. However, as a whole the technique was found to be entirely satisfactory in the small city in which it was tested and is recommended for further testing in other small cities.

NEXT STEP:

DEMONSTRATION OF SIMPLIFIED THOROUGHFARE PLANNING

In preceding chapters a method has been developed and tested for estimating future traffic demand in corridors and at other critical places within a small urban area. This method alone is not sufficient to plan thoroughfares. The forecasting method must be put into the context of the total planning process.

One of the basic premises of a simplified planning process is that the development of alternatives and plan evaluation should be based on acceptable principles and standards of street systems. Furthermore, the existing system and land use development is so restrictive that few realistic courses of action exist. Thus the evaluation of proposals is greatly simplified. This cannot be proved, only demonstrated.

To demonstrate this premise, all of the basic steps of thoroughfare planning must be conducted. This then is the next step in this research on simplified thoroughfare planning, a demonstration of its adequacy in a small city. Such a demonstration is not included in the scope of this project at this time but it is hoped that it will be included in the immediate future.

CONCLUSIONS

This investigation was concerned with reducing the cost and personnel requirements for major thoroughfare planning in small urban areas. A growth factor-corridor method for estimating future demand was developed and tested. Utilizing this method in the urban transportation planning process, it is believed future major deficiencies can be identified and realistic solutions developed. Although the methodology was tested in only one small urban area, the Greater Lafayette, Indiana, Urban Area, the findings may be applicable to many small urban areas.

Conclusions which are made are as follows:

1. The proposed growth factor-corridor method estimated future travel demands sufficiently accurately to indicate the location and number of lanes of needed major improvements.
2. Three parameters were sufficient to indicate the growth of traffic volumes within a corridor. These parameters -- dwelling units, employees, and retail employees -- are easy to obtain for present conditions and to project into the future.

The use of the proposed growth factor-corridor method in the urban transportation planning process might provide the needed forecasts of future travel patterns required for the preparation of sound transportation plans. There are several conditions in small urban areas which indicate sound plans could thus be developed. Important among these conditions are the following:

1. Many traffic problems in small cities may be minimized through traffic engineering measures and physical improvements within the right-of-way of the existing arterial system.

2. Realistic locations for major improvements are severely restricted by the existing street network, external routes and urban development. Therefore, evaluation among any alternatives is greatly simplified.

3. Because the alternatives are limited and travel patterns are easily identified in the small city, a subjective consideration of the travel and other requirements for urban street systems will often lead immediately to the proper course of action.

4. The methodology developed in this research might prove adequate for sound recommendations for a realistic and adequate major thoroughfare plan for a small urban area. By eliminating the origin-destination home interview study and the need for sophisticated trip distribution and traffic assignment techniques, great savings in time, cost and personnel requirements could be realized through the proposed simplified approach to major thoroughfare planning. A demonstration of the use of the proposed methodology is recommended in a small city in the near future.

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APPENDIX A
CORRIDOR DATA FOR GREATER LAFAYETTE, INDIANA

Table A1. 1952 Corridor Data.

Corridor	Dwelling Units	Employees	Retail Employees
Central Area	4,044	5,063	1,708
1	1,144	546	18
2	788	55	30
3	1,045	122	8
4	931	3,651	125
5	1,126	864	39
6	906	743	12
7	2,010	1,576	73
8	88	1,790	0
9	337	61	0
10	355	29	0
11	854	3,599	79
12	315	26	26

Table A2. 1967 Corridor Data.

Corridor	Dwelling Units	Employees	Retail Employees
Central Area	4,171	5,058	2,163
1	1,369	1,297	110
2	1,681	318	100
3	2,930	379	150
4	1,184	6,395	380
5	1,084	2,258	141
6	1,839	2,158	791
7	2,207	1,434	141
8	159	2,336	16
9	1,746	621	112
10	1,562	487	112
11	3,930	7,477	580
12	543	1,557	184

